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NATIONAL WATERWAYS STUDY. ANALYSIS OF NAVIGATION RELATIONSHIPS --ETC(U)

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FINAL REPORT

ANALYSIS OF NAVIGATION RELATIONSHIPS TO OTHER WATER USES

PREPARED FOR THE

U.S. ARMY CORPS OF ENGINEERS
INSTITUTE FOR WATER RESOURCES
WATER RESOURCES SUPPORT CENTER
KINGMAN BUILDING
FORT BELVOIR, VIRGINIA

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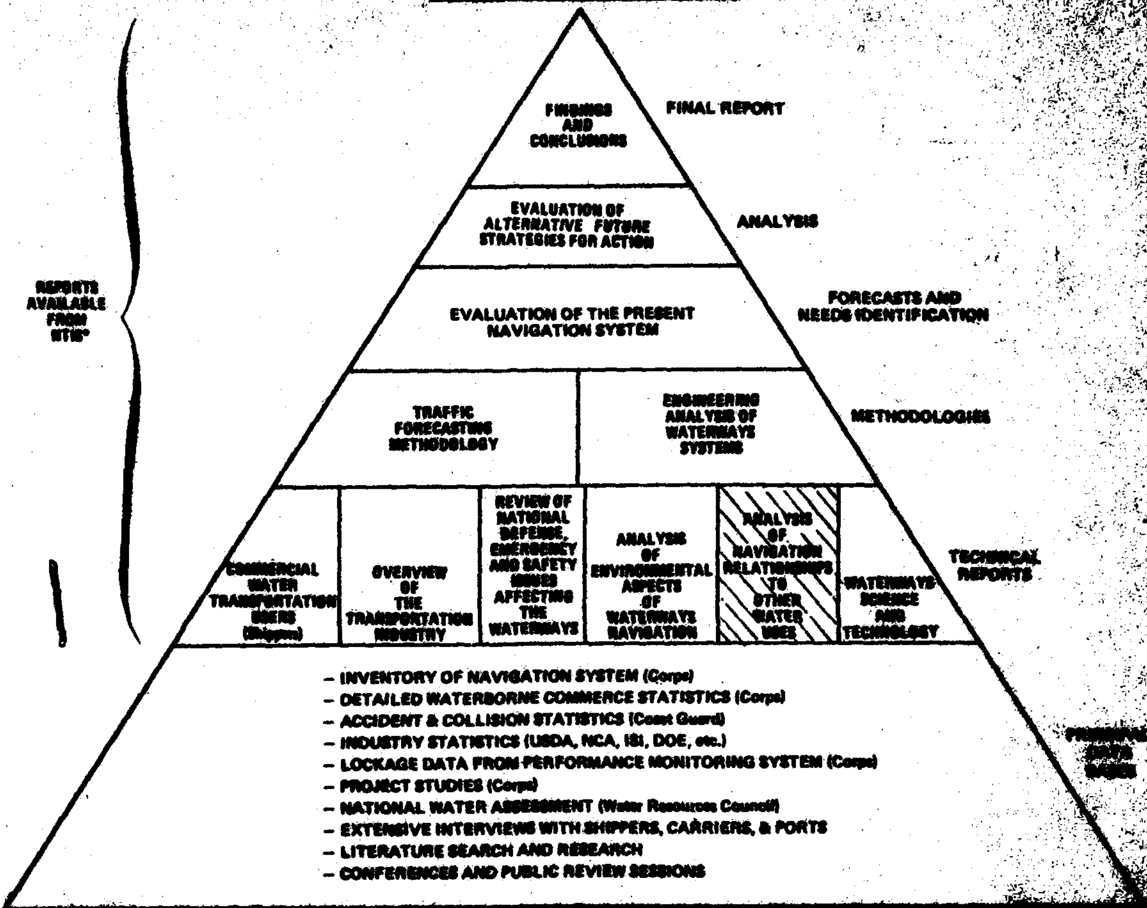

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This report of the National Waterways Study provides a brief summary of the United States multi-purpose waterway system and relevant national water resource policy. Five types of relationships between navigation and other water uses are analyzed: 1) water availability for navigation, 2) reservoir management and instream flow, 3) salt water intrusion, 4) navigation interactions with recreation and 5) beneficial effects of navigation projects.

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THIS REPORT IS PART OF THE NATIONAL WATERWAYS STUDY AUTHORIZED BY CONGRESS IN SECTION 158 OF THE WATER RESOURCES DEVELOPMENT ACT OF 1976 (PUBLIC LAW 94-587). THE STUDY WAS CONDUCTED BY THE US ARMY ENGINEER INSTITUTE FOR WATER RESOURCES FOR THE CHIEF OF ENGINEERS ACTING FOR THE SECRETARY OF THE ARMY.

NATIONAL WATERWAYS STUDY

ANALYSIS OF NAVIGATION RELATIONSHIPS TO OTHER WATER USES

PREFACE

This report is one of eleven technical reports provided to the Corps of Engineers in support of the National Waterways Study by A. T. Kearney, Inc. and its subcontractors. This set of reports contains all significant findings and conclusions from the contractor effort over more than two years.

A. T. Kearney, Inc. (Management Consultants) was the prime contractor to the Institute for Water Resources of the United States Army Corps of Engineers for the National Waterways Study. Kearney was supported by two subcontractors: Data Resources, Inc. (economics and forecasting) and Louis Berger & Associates (waterway and environmental engineering).

The purpose of the contractor effort has been to professionally and evenhandedly analyze potential alternative strategies for the management of the nation's waterways through the year 2000. The purpose of the National Waterways Study is to provide the basis for policy recommendations by the Secretary of the Army and for the formulation of national waterways policy by Congress.

This report forms part of the base of technical research conducted for this study. This report focused on a thorough analysis of available data concerning potential conflicts between navigation and other water uses. The results of this analysis were reviewed at public meetings held throughout the country. Comments and suggestions from the public were incorporated.

This is deliverable under Contract DACW 72-79-C-0003. It represents the output to satisfy the requirements for the deliverable in the Statement of Work. This report constitutes the single requirement of this Project Element, completed by A. T. Kearney, Inc. and its primary subcontractors, Data Resources, Inc. and Louis Berger and Associates, Inc. The primary technical work on this report was the responsibility of Louis Berger and Associates, Inc. This document supercedes all deliverable working papers. This report is the sole official deliverable available for use under this Project Element.

National Waterways Study

FINAL REPORT

ANALYSIS OF NAVIGATION RELATIONSHIPS TO OTHER WATER USES

2

NATIONAL WATERWAYS STUDY

ANALYSIS OF NAVIGATION RELATIONSHIPS TO OTHER WATER USES

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EXECUTIVE SUMMARY

This report first provides a brief summary of the United States multipurpose waterway system and relevant national water resource policy. It analyzes five types of relationships between navigation and other water uses. These are 1) water availability for navigation, 2) reservoir management and instream flow compared with navigation needs, 3) saltwater intrusion from navigation projects, 4) navigation interactions with recreation, and 5) the beneficial effects of navigation projects. Finally, a summary of the effects on these uses of alternative types of strategy action to improve the waterways is presented.

NATIONAL WATER RESOURCES POLICY

A review of published materials and interviews with policy level officials has revealed that there is no formal national water resource policy at the present time in the U.S., except through the influence of legislation aimed at only part of the many water-related activities. Water policy practices have evolved over the years as federal agencies have developed programs to implement legislative mandates and directives from the executive branch. The Water Resource Council attempts to coordinate this set of policies by using methods such as the setting of principles and standards for water resource planning, but it does not have the authority to institute more formal policy measures.

Nineteen water resource task forces (in response to the President's "Water Policy Initiative") are presently working on specific water resource issues. In addition, the Congress is debating major legislation relating to water resource policy.

Of the four areas of policy now under study, only one seems to have discernable impact on future navigation projects from a water resource perspective. The impacts of environmental and water conservation policies are relatively uncertain, although the potential effects appear to be limited. However, they will probably add to the delays in project implementation. Both national and state water

resources management planning and funding policies may have potential impact on large irrigation projects or coal slurry pipelines that may be significant water users. Energy-related policies, however, appear to have the largest potential impact on the type and siting of power plants with water cooling, hydropower development, coal slurry pipeline construction, and synthetic fuel development, which may require significant amounts of water.

AVAILABILITY OF WATER FOR NAVIGATION

The water availability analysis was begun at the river basin level with studies of present water supply and demand and the effects of future changes in water consumption upstream and all waterways with a significant amount of commercial navigation. As a result of this screening process, ten waterway segments in nine NWS regions were identified as having potential water availability conflicts that could affect navigation. These waterways were given a detailed examination in individual case studies, which considered monthly flows over the year in 1975 and 2000, ground water vs. surface water demand, flow regulation and the priorities of water use within each river basin.

This analysis concluded that over the next twenty years there will be problems with water availability for navigation on three free-flowing waterway segments: the Alabama, the Apalachicola and the Missouri. These are just an extension of present problems on the first two rivers, which have relatively limited control of flows, but water consumption upstream will probably result in less water available for navigation. The probability of a shortened navigation season increases significantly by the year 2000.

Slackwater segments of the waterways have no major problem with water availability for navigation because water for lockages constitutes only a small fraction of normal stream flow. However, in three western river basins with waterways (the Arkansas, Red and Ouachita) there will be general water shortages, that will lead to conflicts among users. The causes, effects and consequences of these conflicts will very from basin to

basin, but in these cases, navigation will have essentially a sideline role.

Conflicts in the western river basins will be caused primarily by increases in consumptive use of water for irrigation. Irrigation already accounts for approximately 90% of all water consumption in these areas, and almost all of the cost increase in water consumption is for irrigation.

The Alabama and the Apalachicola presently have extensive navigation problems due to low flows. Tow operators on these older, soft-bottomed rivers are already accustomed to operating "on the bottom" during low flow periods, and they have adapted their equipment somewhat to these conditions. Increases in water consumption in these basins will not be large, but will further complicate efforts to solve these problems.

In the Middle Mississippi the effects upon navigation of increased water consumption upstream are unpredictable. Navigation depths in these segments are significantly affected by sediment loads. Increased water consumption may aggravate shoaling problems by increasing flow extremes during periods of high sediment load, or it could reduce problems by limiting peak flows. Further study of this problem area is recommended.

Control of water storage in most basins on the waterway system is presently fragmented. In addition, navigation is normally ranked fourth or lower in priority for water released (often preceeded by flood control, irrigation, water supply, and sometimes hydropower). This reduces the options available for controlling navigation conditions on the waterways.

RESERVOIR MANAGEMENT AND INSTREAM FLOWS

The reservoir instream flow analysis dealt with case studies of eight waterways. These waterways were identified from field surveys to include all those with reservoirs authorized specifically for navigation releases

plays a set of five segments representing the most significant interactions between navigation and flood control, hydropower, and fish and wildlife flow requirements. A "minimum stream flow envelope" was prepared for each of the five segments selected for instream flow analysis, and this served as a basis for assessing the complementary nature of other instream uses with navigation flow needs.

Five reservoirs or reservoir systems have specifically authorized navigation releases. These are on the Missouri, the Upper Mississippi, the Monongahela, the Arkansas and the Apalachicola Rivers. The Upper Mississippi reservoirs are not longer used for navigation purposes as a result of later downstream projects, but the other four serve present navigation purposes. Their primary use in this respect is to augment flow in low flow months, during the navigation season.

The Missouri reservoirs are operated as a system, for multipurpose use, but the most downstream reservoir (Gavin's Point) smoothes out flows to benefit navigation. The objective of the system for navigation is to provide flows described as "full service to navigation," if reservoir levels permit. This may drop to a minimun service level under drought conditions, and this level of releases is scheduled as long as the water allocated to navigation or multipurpose use is available (usually into November). The navigation season is shortened if less water is available than needed for a full season of minimum flows.

The Monongahela, a tributary of the Ohio, has one reservoir (Tygart) with navigation releases. Since the water requirements for lockages downstream are small, there has been no constraint on navigation in the past. This will continue to be the case unless traffic and/or lock sizes increase by more than four time in the future. Although there is some recreational use of this reservoir, it has not been a significant constraint on navigation releases. This may occur if the lake level is to be drawn down early in the summer season in the future.

The Arkansas River also has one reservoir (Oolagah) with navigation releases. This reservoir has sufficient

capacity to meet lockage water demand downstream for present traffic levels. Future traffic levels could require more than this reservoir can supply, but the other reservoirs in the Arkansas system can pick up the slack.

The Apalachicola River, which flows into the Eastern Gulf, also has one reservoir (Buford) with navigation releases. This system, however, is under some strain, as both recreation and hydropower presently limit the actual releases available for navigation. Recreation is not an authorized use, but has been treated equally with other uses for system operation decisions. This situation will get worse in the future as both these conflicting uses will probably become more influential.

From the analysis of instream flows in five river basins (the Columbia, Missouri, Arkansas, Cumberland and the Alabama) it appears the waterway flows for other use supply, on the annual low flow periods. Hydropower peaking, however, creates problems below certain dams on three of these rivers due to daily or weekly variations in flow, thereby constraining navigation. If hydropower peaking becomes more pronounced on these systems, as forcast, this may conflict significantly with navigation, but only on these relatively peripheral components of the national waterway system.

Flows for fish and wildlife needs are not well defined at present. These are generally complementary to navigation, but more research is needed on this subject.

SALT WATER INTRUSION

Salt water intrusion due to navigation projects has been raised as a concern in several coastal waterways due to its potential impact on water supplies and fish and wildlife habitat. This issue was investigated for three areas: San Francisco Bay, the GIWW near the mouth of the Mississippi, and the Chesapeake and Delaware Bays. There are presently salt water barriers protecting fresh water sections of the GIWW, which were built as a mitigation measure to protect irrigation water supplies in southern Louisiana. These barriers impede navigation to some extent and enlargement of lock is proposed in two cases

(Vermilion and Calcasieu). This enlargement should not have significant effects on salt water intrusion.

A more important issue involves proposed channel deepening projects in these areas. These projects may allow the salt water wedge, which advances upstream, in low flow periods, to threaten municipal water supply intakes. They may also allow more infiltration into fresh water aquifers and alter wetland vegetation and fishery locations. In most cases, however, a careful project design, using hydraulic simulation models, and the variety of mitigation measures which are available can reduce potential salt water intrusion impacts to insignificant levers.

RECREATION - NAVIGATION INTERACTION

The analysis of recreation interactions with navigation dealt with six major settings and four groups of activities. The settings included free-flowing rivers, navigation locks, pools, reservoirs, bays and ports. The activities are boating, fishing, swimming and water-oriented shore activities. This analysis involved fourteen case studies of conflicts or beneficial effects on individual segments.

Recreation use of the waterways is varied and extensive compared with other uses. Interactions between recreation and commerical navigation occur most frequently in pools and channels, at locks and dams, and in ports and harbors. Reservoirs subject to navigation releases also offer a potential arena for conflicts between recreation and navigation interests. Recreational boating has the most obvious conflicts but other kinds of recreation can be affected as well.

High levels of recreation are found on the Upper Mississippi, the Tennessee and Cumberland Rivers, the Arkansas-Verdigris System, the Great Lakes and the Middle Atlantic Coast. High levels of recreation use also occur on coastal segments, but this use is not well documented, and does not usually interfere with commercial navigation. Several smaller river systems show moderately high use

throughout the waterway system; and reservoirs have high use which is sensitive to major changes in water level.

Conflicts occur most frequently at points in the waterway system with high recreation use where commercial and recreation activities compete for the same space. Conflicts are generally more intense near urban areas, in narrow channels and locks and in certain ports where the siting of facilities produces competing use of the waterways.

At the present time significant conflict areas include the Upper Mississippi, the Ohio, the Arkansas-Verdigris, and the Columbia Rivers, and Chesapeake and San Francisco Bays. Reservoirs associated with commercial navigation present the potential for future conflict, but little is experienced now.

The categories of navigation activity which impinge upon recreation uses are:

1. planning and design of facilities.

2. operation and maintenance of facilities.

3. commercial navigation (including traffic levels, fleeting and port activities).

Most of the existing conflicts arise from the operation and maintenance of waterways facilities. Good design and planning for integrated use, however, has a significant effect on subsequent operations in providing lower levels of conflict, and beneficial recreation uses as will (e.g., urban access points, and beach nourishment). The present planning and design efforts in this regard vary tremendously from one waterway to another, but have been increasing in recent years. More systematic planning for recreation in navigation project design and operation is recommended, as well as incorporation of recent research findings on mitigation measures and increasing beneficial effects.

Commercial traffic generates demand for water space, particularly in ports and fleeting areas. These are not

presently a major conflict issue except in isolated sites, but competition for water space and associated land sites near urban areas may become significant if waterway traffic grows rapidly. It is recommended that future port development or expansion be planned with these interactions in mind, so that these competing uses are accommodated with the least conflict.

Recreation demand was forecast for several types of facilities on those waterway segments where potential conflicts might occur. These included 140 navigation pools, locks on 22 segments, and four reservoirs with navigation releases. Relatively slow growth in recreation use is forecast on the waterways due to population declines in many older waterway areas, competition from other recreation sites, and the effects of rising energy prices. Recreation use of the waterways will increase fastest near urban areas with increasing populations. Some pools on the other hand are forecast to lose some recreation use in the future. Land-based recreation activity along the waterways will remain the dominant use.

Recreational lockage demand, which is mainly by larger motor boats, is expected to remain essentially the same as present levels, on the waterways examined. This is consistent with the effects of rising gasoline prices on motor boating activity, and lower population growth in the future.

Reservoir recreation use will continue to grow significantly, where capacity at individual sites is available. Recreational boating in port areas is expected to grow, with Oregon-Washington and Florida coasts growing rapidly. This growth is expected to be accommodated primarily at marinas outside the ports themselves, thus reducing potential conflicts.

BENEFICIAL EFFECTS OF NAVIGATION PROJECTS

Five case studies were made of the beneficial effects of navigation projects that were identified through interviews with Corps field offices. These case studies concluded that there are a variety of benefits from navigation projects for other water users. Many of these

beneficial effects are built into multipurpose project designs (e.g., flood control and hydropower); but these are evident, and are not discussed in this section. The less evident beneficial effects addressed in this report concerned recreation, fish and wildlife support, and regional socioeconomic development.

Projects built primarily for navigation purposes have provided major new recreation resources in drier areas. They have also improved recreational fishing in the Arkansas due to lower sediment levels and created new fish habitats in oxbow lakes resulting from navigation cutoffs.

Dredged materials have been made useful in certain areas for beach creation and nourishment, as well as for the creation of wetland habitat. Pilot projects for beneficial use of these materials have been carried out in the Upper Mississippi and should be extended to other areas.

On a more general scale, the socioeconomic effects of navigation projects have been investigated for the Arkansas basin. While these benefits are difficult to spearate from other growth influences, there appears to be significant positive impacts.

THE EFFECTS OF ALTERNATIVE WATERWAY IMPROVEMENT ACTIONS ON OTHER WATER USES

There are few strategy actions that will have a significant effect on water consumption. The primary action is reservoir regulation which releases water for navigation purposes that could be used upstream for water supplies or irrigation. Increasing channel dimensions may also require increased discharge on certain waterways. This could lead to reduced water availabitity for upstream consumptive users such as irrigation and municipal interest. Extending the navigation season is a second action that also requires increased discharges and may affect the utilization of upstream reservoir storage volumes. Downstream consumptive users are favorably affected by actions that reduce the possibility of accidents involving hazardous materials.

There are several possible strategy actions which may affect instream uses of the waterways. Increasing the channel deminsions will require additional flows on certain waterways. Actions to improve flow reliability through regulation require changes in reservoir release schedules which will have varying effects on flood control, hydropower and fish and wildlife habitats depending on the waterway segment. The use of dredging or river training techniques to improve channel dimensions will also have a significant effect on fish and wildlife habitats. The actual impacts can be either positive or negative but can only be described on a site-specific basis.

Actions to extend the navigation season through the provision of winter lockages and the maintenance of open channels have potentially significant impact on fish and wildlife interests. Changing ice conditions to open water will have effects on aquatic organisms, although no judgments as to the desirability of such changes are possible except on a site-specific basis.

Actions intended to reduce the environmental inpact of dredged material disposal should have a positive effect on fish and wildlife habitats and recreations sites. These actions include the development of techniques to reduce the necessity of large dredging volumes and the increased use of dredged material for beneficial purposes. Identified beneficial purposes include the creation of industrial sites through land fill, the creation of marshlands for wildlife habitats, and beach enrichment.

Actions to improve waterway safety and to reduce the effects from spills of hazardous materials will have a positive effect on water quality and recreation. This will, in turn, reduce the incidence of damage to aquatic habitats for fish and wildlife.

Increasing shipper commitments to the waterways through long range planning should allow all waterway users an increased degree of confidence in planning their respective activities. Greater reliability of waterway management, the identification of future needs, and the adoption of commitments will permit a higher efficiency in multipurpose use of the waterways.

Non-structural actions to increase lock capacity include the scheduling of recreational lockages. At some locks the quality of recreation is reduced because of long delays in locking through. Major structural changes in locks may include the provision of separate facilities for recreational craft. These may include separate locks or facilities wuch as a "sling" to lift the craft over the dam to the opposite side. These actions would have a significant positive effect on recreation.

Actions to improve navigation conditions through reservoir regulation have significant impacts on recreation both in the reservoir pool and downstream. Extreme high or extreme low pool levels have a direct bearing on user satisfaction. There may be only a narrow range of pool stage or river flow conditions that are conducive to good recreation. Boating safety provided by adequate clearances around bridges and marinas, improved navigation aids, and better traffic control technology are all important actions for recreation interests.

The list of strategy actions contains few items that directly affect the problem of salt water intrusion. Those actions considered significant include channel deepening to increase waterway dimensions, flow regulation to improve navigation conditions, rehabilitation of locks to reduce their vulnerability to failure, and better long range planning. Channel deepening and/or reduction of flow may facilitate the movement of saline water into areas which threaten irrigation, municipal water supply, or fish and wildlife habitats. Salt water barrier locks require particular attention to maintenance in order to avoid failures and resulting salt water intrusion into fresh water zones. Finally, improved long range planning is expected to provide water users with better assurances concerning the future of water quality along coastal segments. Mitigation measures to reduce damages produced by projects which may create salt water intrusion problems should be included in the planning efforts, as these can effectively eliminate such problems in most cases.

OVERALL CONCLUSIONS

Interactions between navigation and other water uses on the commercially navigable United States waterway

system are more limited than the numbers of multipurpose uses would imply. There are only three river basins with definite future water availability conflicts that are likely to affect navigation, and four others that would only create problems under drought conditions. All of these are relatively minor waterways in terms of the total tonnage they carry.

Four waterways have reservoirs with navigation releases. In only one of these cases is navigation constrained by other uses.

Three waterways (including two in the first category above) have present conflicts with the timing of hydropower releases. This problem area will probably increase with greater hydropower peaking operation in the future, but is limited to certain locations below large hydropower facilities. In all waterways hydropower, flood control and low flow augmentation releases are complementary to navigation needs except for occasional timing problems.

Recreation is the most pervasive use of the waterway system that interacts with commercial navigation. Virtually all segments have some recreation use, but pools, locks, ports and harbors are the use areas which conflict most with commercial navigation. The present conflict areas include the Upper Mississippi, the Ohio, the Arkansas-Verdigris, and the Columbia Rivers, as well as Chesapeake and San Francisco Bays. These conflicts are not severe at the present time, but may grow with increased commerical navigation uss of the waterways.

The pattern that emerges from the discussion of effects of Corps actions on other water users is that the major linkage is through effects on flow and related reservoir regulation. All of the impacts on consumptive uses, part of the recreation and part of the fish and wildlife impacts are tied to these two flow-related aspects of the waterway system.

Recreational boating is also affected by locks and their operating procedures. In addition, there are minor

safety impacts of other Corps actions, and recreation is affected negatively by dredging and positively by creation of beaches or oxbow cutoffs, or other actions.

Further research is recommended in each area of the above analysis where data are weakest. However, the available data appear sufficient for national-level analysis in its present form. More detailed investigation of site and project-specific issues are recommended for those waterway segments with conflicts or complementary uses which are identified in this report.

I - INTRODUCTION

This report serves as technical support for the NWS analysis of the capability of the United States National Waterway System to meet future navigation needs. It covers the methodology, findings and conclusions of the work carried out in Element G concerning the interactions of commercial navigation with other users of the waterway system.

The report is composed of nine sections including this introduction. The following sections are: 1) The Multi-purpose Waterway System, 2) Water Availability for Navigation, 3) Reservoir Management and Instream Flow, 4) Salt-water Intrusion, 5) Recreation Interaction with Navigation, 6) Beneficial Effects of Navigation Projects, 7) Recommendations for Further Analysis, and 8) Conclusions.

The general approach to this part of the NWS was to thoroughly analyze available data concerning potential conflicts with navigation and other water uses, screen all waterway systems segments for potential conflicts or beneficial uses, and analyze in detail those segments which represent the range of significant conflicts or interactions with navigation. This approach involved a substantial amount of field work for data collection and interviews, but no original in-depth research was attempted since the study focus is on the national level.

Several meetings were arranged to provided periodic input from concerned interest groups and technical experts in the various disciplines covered in this report. These inputs were taken into account in the design of the study scope and in the selection of relative emphasis for the analysis. Comments on preliminary conclusions derived from four citizen meetings in different parts of the country were also taken into account.

Conclusions are drawn on the national or regional (river basin) levels, although most of the anlysis took place on the analytic segment level. The regions and their associated analytic segments are presented in Table I-1. The level of detail of the analysis was selected for

appropriateness at the segment level and the regional level, although in some cases, analyses were carried out at specific locations on a segment to identify the characteristics of interactions that take place on the waterways between tows and other users. The resulting conclusions are thereby supported at a level of detail consistent with the nature of the National Waterways Study.

Table I-1

NWS REGIONS AND ANALYTIC SEGMENTS

REGION NO.	REGION NAME	ANALYTIC SEGMENT NO.	ANALYTIC SEGMENT NAME
1.	Upper Mississippi	1.	Upper Mississippi River
2.	Lower Upper Missippi	2.	Lower Upper Mississippi River
		3.	Middle Mississippi River
3.	Lower Mississippi	4.	Lower Middle Mississippi River
		5.	Upper Lower Mississippi River
		6.	Lower Mississippi River
4.	Baton Rouge to Gulf	7.	Mississippi River (Baton Rouge)
		8.	Mississippi (New Orleans to Gulf)
		25.	Ouachita and Red Rivers
		26.	Old and Atchafalaya River
		27.	Baton Rouge Bypass
5.	Illinois River	7.	Illinois Waterway
6.	Missouri River	10.	Missouri River
7.	Ohio River	11.	Upper Ohio River
		12.	Upper Middle Ohio River
		13.	Middle Ohio River
		14.	Lower Middle Ohio River
		15.	Lower Ohio River
		16.	Monongahela River
		17.	Allegheny River
		18.	Kanawha River
		19.	Kentucky River
		20.	Green River and Barren River
		21.	Cumberland River
8.	Tennessee River	22.	Upper Tennessee
		23.	Lower Tennessee
9.	Arkansas River	24.	Arkansas and Verdigris
10.	Gulf Coast West	28.	GIWW West (East)
		29.	GIWW West (Middle)
		30.	GIWW West (South)
		34.	Houston Ship Canal
11.	Gulf Coast East	31.	GIWW East (West)
		32.	GIWW East (East)
		33.	Florida Gulf Coast & Okeechobee Waterway
		38.	Apalachiocola, Chattahoochee, Flint River
12.	Tombigbee - Alabama Coosa-Black Warrior River	35.	Black Warrior River
		36.	Tombigbee-Warrior and Alabama-Coosa
		37.	Tennessee-Tombigbee Waterway
13.	South Atlantic Coast	39.	Florida/Georgia Coast
		40.	Carolinas Coast
14.	Middle Atlantic Coast	41.	Chesapeake and Delaware
		42.	New Jersey/New York Coast
15.	North Atlantic Coast	44.	Upper Atlantic
16.	Great Lakes/St. Lawrence Seaway New York State Waterway	43.	New York State Waterways
		45.	Lake Ontario and St. Lawrence Seaway
		46.	Lake Erie
		47.	Lake Huron and St. Marys River
		48.	Lake Michigan
		49.	Lake Superior
17.	Washington/Oregon Coast	50.	Puget Sound
		53.	Washington-Oregon Coast
18.	Columbia-Snake Waterway/Williamette River	51.	Upper Columbia and Snake Waterway
		52.	Lower Columbia, Williamette River
19.	California Coast	54.	Northern California
		55.	San Francisco Bay
		56.	Central/South California
20.	Alaska	57.	Southeast Alaska
		58.	South Central Alaska
		59.	West and North Alaska
21.	Hawaii and Pacific Territories	60.	Western Pacific
22.	Caribbean	61.	Caribbean

II - THE MULTIPURPOSE WATERWAY SYSTEM

This section describes the multipurpose system, the relative importance of navigation, federal regulations relative to navigation and other uses, and national water resource policy.

DESCRIPTION OF THE MULTIPURPOSE SYSTEM

The United States National Waterway is composed of many different parts which have very different characteristics. The waterways which make up the system can be divided into inland and coastal. Inland waterways, in turn, are divided into free-flowing and slack water (canalized segments. Coastal segments can be extensive channels, such as the Gulf Intracoastal Waterway (GIWW), or merely composed of port areas where commercial tows and deep draft vessels travel in relatively short channels.

All of these segments have quite different uses, some of which conflict with commercial navigation use of some of which complement this use. A list of the authorized and actual present uses of the national waterway system is given in Table II-1, and a map of the system showing the geographic distribution of these uses is provided in Figure II-A.

RELATIVE IMPORTANCE OF NAVIGATION

Although the waterway system segments are all authorized for navigation (by definition) and appear to be designed primarily for navigation purposes, in many cases, commercial navigation is frequently given lower priority than other uses. In the 15 western states with non-riparian water law, upstream users have legal precedence over navigation. In these regions navigation usually comes fourth (behind flood control, irrigation and water supply) and sometimes fifth, behind hydropower, as well.

In the other states navigation has a higher priority. In the coastal areas navigation is frequently the primary use, although other uses are often served.

Figure II-A

Multipurpose Uses of the United States Waterway System

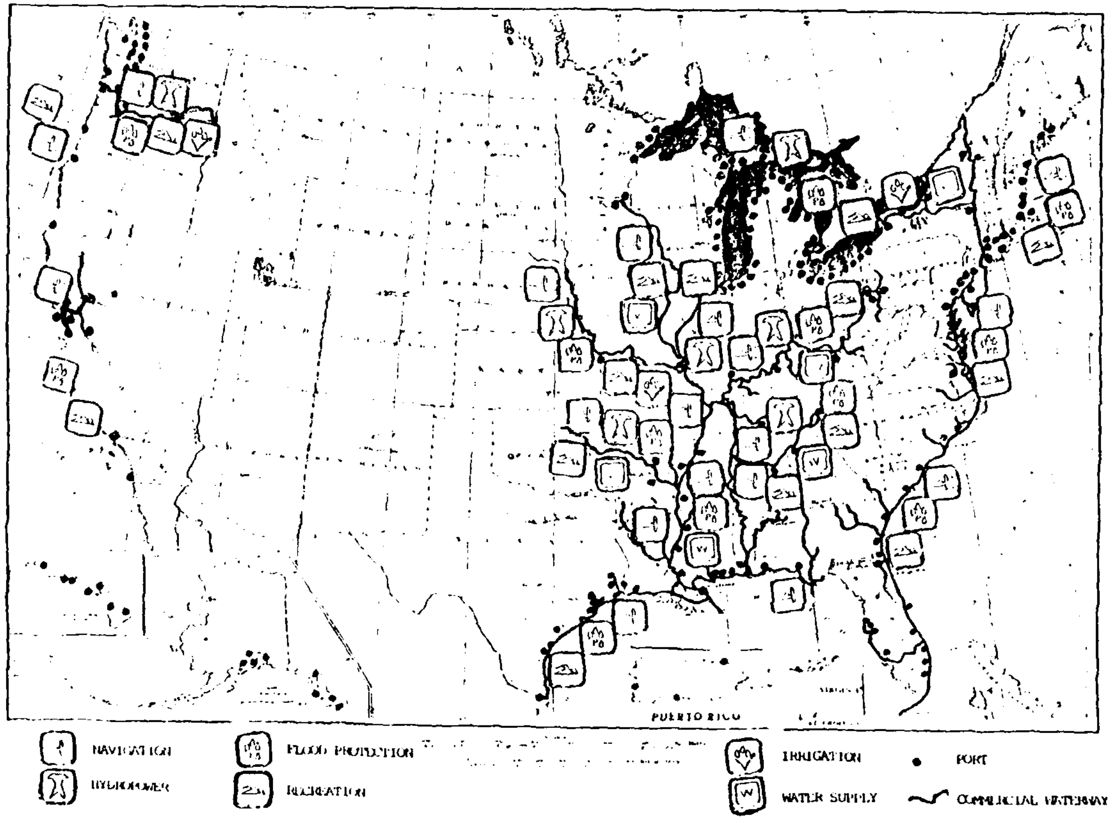


Table II - 1

Authorized and Present Uses of the
United States Waterway System
(as defined for the National Waterways Study)

NWS Region	Segment Types	Authorized Uses	Present Uses
1. Upper Mississippi	S	NRB	NWRBAFC
2. Lower Upper Mississippi	S,F	N	NR
3. Lower Mississippi	S,F	NP	NPW
4. Baton Rouge to Gulf	S,F	NPWRBQC	N
5. Illinois River	S	NPQ	NRBQHZ
6. Missouri River	F	NPRFIHZ	NPRFQIZ
7. Ohio River	S	NPRBQHDZ	NPWRBHCGAFEQZ
8. Tennessee River	S	NPHD	NPWRBH
9. Arkansas River	S,F	NPWRFH	NPWRFH
10. Gulf Coast West	C	NPZ	NPB
11. Gulf Coast East	C	NPBR	NPRB
12. Tombigbee - Alabama Coosa and Black Warrior	C	ND	NRBFECD
13. South Atlantic Coast	C	NPRBD	NPRBD
14. Mid Atlantic Coast	P	NPBFDZ	NPRBZ
15. North Atlantic Coast	S	NPWRBZ	NPWRBIH
16. Great Lakes - St. Lawrence Seaway - NYS Waterway	L	NRBFHZ	NWRBFQCHZ
17. Washington - Oregon	C	NRB	NRB
18. Columbia - Snake Waterway Willamette River	S	NPRIHG	NPRBIHPQ
19. California Coast	C,S	NPBD	NPBDRAFE
20. Alaska	P	NBDZ	NBDZ
21. Hawaii and South Pacific Territories	P	N	N
22. Caribbean	P	NPRB	NBRFE

* Anywhere on waterway in region.

Types: S=Slackwater
F=Freeflowing
C=Coastal
P=Ports only
L=Great Lakes

Uses: N=Navigation
P=Flood Protection
W=Water Supply
R=General Recreation
B=Boating Recreation
C=Cooling Water
G=Lowflow augmentation
H=Hydropower
D=National Defense
Z=Other
A=Aesthetics
F=Fish and Wildlife
E=Environmental
Q=Water Quality
I=Irrigation

More information is given on these relative priorities in the following sections.

FEDERAL REGULATIONS CONCERNING NAVIGATION AND OTHER USES

There are a substantial number of regulations shown in the Federal Code of Regulations, which covers direct relations between navigation and other water uses. The most significant of these are summarized in Table II-2.

In addition there are many regulations which indirectly affect the relationships between navigation and other water uses. These regulations are not examined explicitly in the present study. However, their effects are included in implicitly in the flow analysis of Section IV, the saltwater intrusion analysis of Section V, and the recreation analysis of Section VI.

Table II -2

Summary of Significant Federal Regulations Affecting Commercial Navigation

NWS Region	Type of Regulation	Other Uses Involved
1	Administrative, lockage, vessel Reservoir/pool, Discharge Logging	Recreation, Hydropower
2	Administrative, lockage	Recreation
3	Administrative, lockage, vessel, logging	-
4	Administrative, lockage	Recreation
5	Administrative, lockage Reservoir/pool	Recreation
6	Administrative, logging	Recreation
7	Administrative, lockage	Recreation
8	Administrative, lockage	Recreation
9	Administrative, lockage	Recreation
10	Administrative, lockage	Recreation
11	Administrative, lockage	Recreation
12	Administrative, lockage	Recreation
13	Administrative, lockage	Recreation
14	Administrative, lockage discharge	Recreation, Hydropower
15	Administrative, lockage, vessel	
16	Administrative, lockage, vessel discharge, Reservoir/pool, logging	Recreation
17	Administrative, logging	-
18	Administrative, lockage, logging	Recreation, Hydropower
19	-	-
20	-	-
21	-	-
22	-	-

Logging - Regulations restricting raft types or sizes and periods of logging runs.

Administrative - Regulations dealing with general use, operation and controlling agencies.

Lockage - Regulations dealing with procedure of lockage, vessels type and size restrictions, lockage schedules and procedures.

Vessel - Regulations restricting cargo anchorings in specific areas.

Reservoir/Pool - Regulations establishing minimum or maximum pool levels.

Discharge - Regulations restricting flow or rate of discharge.

III - ANNUAL FLOW AVAILABILITY AND NAVIGATION

The aim of this analysis is to identify those waterway system segments which have a potential conflict between other water uses and navigation which is mediated through stream flow. This conflict can be felt through long-term depletion of flow as more upstream consumptive uses are accommodated, through annual releases of flood water, or through daily or weekly variations in hydropower plant operations. Reservoir management is only briefly described in this section where it relates to water availability. A more detailed analysis of this topic is presented in Section IV.

METHODOLOGY

The methodology applied here is relatively extensive but straight-forward. The water demand forecasts in the Second National Water Assessment (NWA), prepared by the Water Resources Council with substantial regional input, were used as a starting point. These forecasts were revised to reflect the different macro-ecomonic futures which serve as the basis for the National Waterways Study (NWS) forecasts. The revised water demand forecasts were then compared with available flows by NWS segment to identify segments with potential flow problems, and these were then analyzed in more detail to examine the potential impact on navigation. The steps of the analysis were as follows:

1. Summary of NWA forecasts by subarea and major water use.

2. Analysis of unit water use by basin.

3. Modification of water demand forecasts to correspond with four NWS macro-economic forecasts.

4. Analysis of navigation requirements for water by segment.

5. Comparison of water demand with available supply by segment in the worst month (usually July or August).

6. More detailed analysis of water demand for segments identified in step five to determine the potential effects over the year, level of water control, and other factors which influence the impact on navigation.

This analysis proceeds at an area of level for the first three steps, since demand for water comsumption is related to area-wide economic activity in the river basin, and the sum of basin activity has a relationship to the amount of water available in the downstream NWS segments. The supply and demand for water at the NWS segment level is compared for the first time in step 5. The base year of 1975 was selected for this analysis because the principal data sources (NWA) provides detailed information for this year which is not available for later years. The year 2000 is used as the principal forecast year screening purposes.

(a) Consumptive Uses

The National Water Assessment has estimated existing (1975) and future (2000) demand for water for a variety of user categories. Water demands were computed for 21 major drainage basins called NWA regions and each region was divided into subregions called Aggregated Subareas (ASA's). The ASA is generally the finest level of detail of demand projections available in a nationally consistent format.

NWA data was first summarized for those regions related to non-title NWS segments, and grouped into seven use groups for this analysis. These uses are:

- domestic and commercial water supply.
- power plant cooling.
- fuels mining.
- minerals mining.
- industrial water supply.

- irrigation water supply.

- livestock.

Table III-1 shows the ranking of these uses in the selected regions.

This analysis indicated that minerals mining and livestock were not larger enough to be a significant use and could be included in a miscellaneous category. The other five uses were highly ranked in at least one region, and were given more detailed analysis. (More detailed on segment selection and water user analysis is provided in Appendix A).

The major projects that will affect future water available for navigation are six large irrigation projects in the Missouri River Basin and four proposed coal slurry pipelines. Two other coal slurry pipelines originating in Western Colorado and Utah were deemed not pertinent to navigation conflicts. Seventeen proposed synthetic fuel plants were also examined closely for their potential impact on water consumption in the future, but they were found to be of minor significance in terms of segment level water consumption based on macro-economic forecasts. (They make up less than 3% of any segment's water consumption demand in 2000).

The significant projects are listed in Table III-2. All of these projects could experience potential constraints on their implementation, and are treated with explicit assumptions in the following analysis of future water use.

Four water demand forecasts based on NWS macroeconomic forecasts were generated for each ASA relevant to NWS segment water availability. These forecasts are called: Base Case, Bad Energy, Larger Government, and Less Government. The Base Case continues present trends with no major shifts in the future. The Bad Energy forecast assumes a faster increase in imported oil prices than the trend would indicate, and takes into account all the economic shifts that this would imply. The Less Government and Larger Government forecasts assume a lower or higher proportion of government spending in the national

Table III-1

Water Consumption, Ranking of Uses by Region
(where consumption ≥10% of regional total)

	NWA Region	Domestic and Commercial 1975	2000	Power Plant Cooling 1975	2000	Fuels Mining 1975	2000	Minerals 1975	2000	Industrial 1975	2000	Irrigation (ave. yr) 1975	2000	Livestock 1975	2000
1	New England	2	2	*	*	*	*	*	*	1	1	*	*	*	3
2	Mid-Atlantic	1	2	*	3	*	*	*	*	2	1	3	4	*	*
3	S. Atlantic Gulf	2	4	*	3	*	*	*	*	3	2	*	*	*	*
4	Great Lakes	2	3	*	2	*	*	*	*	1	1	*	*	*	*
5	Ohio	2	3	3	2	*	*	*	*	1	1	*	*	*	*
6	Tennessee	2	*	3	2	*	*	*	*	2	2	*	*	*	*
7	Upper Mississippi	1	3	5	1	*	*	*	*	*	2	4	4	3	5
8	Lower Mississippi	*	*	*	*	*	*	*	*	*	*	1	1	*	*
10	Missouri	*	*	*	*	*	*	*	*	*	*	1	1	*	*
11	Arkansas-White-Red	*	*	*	*	*	*	*	*	*	*	1	1	*	*
17	Pacific Northwest	*	*	*	*	*	*	*	*	*	*	1	1	*	*
18	California	*	*	*	*	*	*	*	*	*	*	1	1	*	*

NOTE: *Less than 10% of total

SOURCE: NWA statistical appendices, Volumes A-1 and A-2 data, ranked by the consultant

Table III-2

Significant Projects for the Analysis of Water Availability

A. Major Irrigation Projects

Name	River Basin	Maximum Acres Irrigated	Maximum Water Demand (MGD)
1. Oahe Unit	Missouri	190,000	382
2. Nebraska Mid-State Unit	Missouri	140,000	281
3. Garrison Division Unit	Missouri	96,000	193
4. Loup River Columbus Unit	Missouri	53,000	106
5. O'Neill Unit	Missouri	50,000	89
6. Buffalo Bill Dam Project Modifications	Missouri	10,000	20

B. Coal Slurry Pipeline

Name	Owner	River Basin	Maximum Coal Capacity (mil. tons per year)	Maximum Water Demand (MGD)
1. ETSI	Kansas-Nebraska Natural Gas Co. and Energy Transp. Systems	Missouri	25.0	16.4
2. Texas Eastern	Brown & Root and Eastern Transmission	Missouri	22.0	14.5
3. Gulf Inter-state	Gulf, Inter-state Engineering & Northwest Pipeline Co.	Missouri	10.0	6.6
4. Boeing Pipeline	N.A.	Ohio	[illegible]	[illegible]

economy, and shifts in relative growth rates of industrial sectors to reflect public spending patterns.

The accurate water consumption in each ASA by use group was adjusted to fit the NWS macroecomonic forecasts by using the ratio of irrigated land (or other key variable) forecast by NWS compared with NWA forecasts. The results are discussed in section III(b) below.

(b) Water Flow Requirements for Navigation

Water flow needs for navigation are of two types. Where the segments are canalized, this consists of lockage water requirements. Where the segments are free-flowing, this flow is defined here as that necessary to maintain authorized channel depth at present levels of sediment deposition and dredging effort.

Lockage water requirements in a segment are determined by the lock with the largest volume of water used in the segment. This volume is determined by a combination of the number of lockages, the type of lockages, and the volume of the lock chamber. The operation of a lock can be described as a series of cycles in which the lock chamber is emptied and filled again. The number of cycles varies with the type of lockage. (A schematic diagram of a lock is shown in Figure III-A).

In a downbound single lockage, a vessel enters ;the lock chamber from the upper pool. The chamber is then drained to the level of the lower pool. When the water level in the chamber reaches the level of the lower pool, the lower ga s are opened and the vessel exits. The cycle is com eted when an upbound level of the upper pool by the filling of the lock chamber, and exists into the upper pool. In the course of each cycle, water taken from the upper pool is released to the lower pool.

The lockage water requirements calculated from analysis of the key lock in each canalized segment: The lock whose water requirements determined segment needs is also given.

For free-flowing segments the design flow is given in this table. This flow was that used in the engineering design of a navigation project, above which the channel can be maintained at authorized depth with the planned level of dredging. For older rivers whose depth is roughly related to how this theoretically represents the minimum present water needs. For other rivers, such as the Middle and Lower Mississippi, this number has little meaning, as depth is determined primarily by other factors than average flow. (e.g. rate of flood recession and dredging). Further discussion of this problem area is given in the text below. All flows are given in millions of gallons per day (MGD) in order to relate them to demand which is normally given in these units (1MGD = 1.6 cfs).

Another way of defining navigation needs on free-flowing segments is to define the present loading practices of towing companies and determine their reference points for light-loading of barges. This method defines a behavioral loading pattern in relation to flow, which may also be a valid definition of waterway navigation needs. This approach is developed for selected segments in the text below.

(c) Comparison of Water Demand and Supply

This step is essentially a screening step to identify those segments which have potential flow problems that could affect navigation. For canalized segments, the analysis focuses on average water supply and demand in the most critical month using forecasts to the year 2000, and compares the residual flow to the minimum flow required for lockage needs. For free-flowing segments, the analysis focuses on the percent reduction in future low flow due to increased water consumption upstream of each segment. It was assumed that if a segment had no water problem in its most critical month, it would not have a problem during the rest of the year.

A third type of analysis was conducted for the Great Lakes segment. In their case the long-term effects of future water consumption on water levels was estimated since it is a question for them of water level rather than flow.

Instream water availability for navigation was based on statistical stream flows and hydrographs developed for the National Water Assessment. This date source was selected beacuse it would provide the same statistical streamflow measures based on the same set of assumptions for all segments. There is no other data base which can supply this kind of information, consistently, on a national level.

The basic unit for reporting information in the National Water Assessment is the subarea. Subareas are divisions of the twenty regions which cover the whole United States. For further detailed descriptions of the regions and subareas contact the Water Resources Council in Washington, D.C.

Figure III-B shows the flow relationships between NWS Segments and NWA Subareas. In this flow analysis certain segments were combined. These were: 6 and 26; 11 and 12; 13, 14, ana 15; 35 and 37; and 51 and 52. Segments 6 and 26 were treated as a single segment because they are parallel routes which use the same river for a water supply. The other grouped segments were combined because they are parallel routes which use the same river for a water supply. The other grouped segments were combined because it was not considered necessary to disaggregate the consumptive water demand to the same level of detail as the analytic segments. These segment groups were relatively homogeneous. Therefore, the grouping should not lead to a significant distorsion in the screening results.

NWS Segments 21, 25, 36, 38, and 51/52 contain both canalized and free flowing sections. These segments were analyzed for potential flow problems both along the free flowing section and at the key lock and dam.

(d) Detailed Analysis of Selected Segments

The more detailed analysis of selected segments provides a monthly analysis of supply and demand for 1975 and 2000 for seven segments with potential flow problems, and an analysis of water consumption effects on Great Lakes

Figure III - A

Schematic Diagram of a Lock
(Longitudinal Crossection)

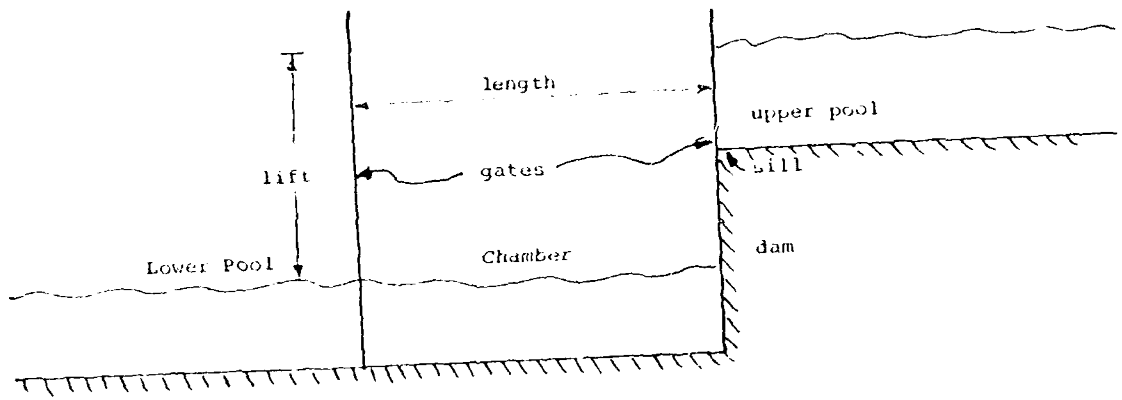


Table III-3

Design Flows and Lockage Water Demand

Segment	Control Point	Canalized Water Demand (MGD)	Free Flowing Design Flow (MGD)
1	L/D 19	612	
2	L/D 26	219	
3	St. Louis Gauge		34900
4	Memphis Gauge		93800
5	Vicksburg Gauge		112500
6, 26	Baton Rouge Gauge		117000
9	Brandon Rd L/D	207	
10	Sioux City Gauge		21428
11,12	Markland	507	
13,14,15	MacAlpine L/D	540	
16	Maxwell L/D	128	
17	L/D #3	31	
18	Winfield L/D	109	
20	L/D 1	37	
21	Barkley L/D	180	
21	Below Barkley L/D		6400
22	Winson L/D	[illegible]3	
23	Kentucky L/D	[illegible]00	
24	Dardanelle L/D	120	
25	Jonesville L/D	12	
25	Below Montcla L/D		2600
33	St. Lurie L/D & Ortona L/D	9+7=16	
35, 37	Coffeeville L/D	123	
36	Claiborne L/D	33	
36	Below Claiborne L/D		5600
38	George L/D	44	
38	Chatahoochie		6000
39	Buckman L/D	34	
42	Troy Lock	17	
51, 52	John Day L/D	138	
51, 52	Portland		64600

SOURCES: Consultant Calculations and Corps of Engineers, Inland Navigation System Analysis, Table B.

Figure III - B

Flow Systems for NWS Segments and NWA Subareas Analyzed

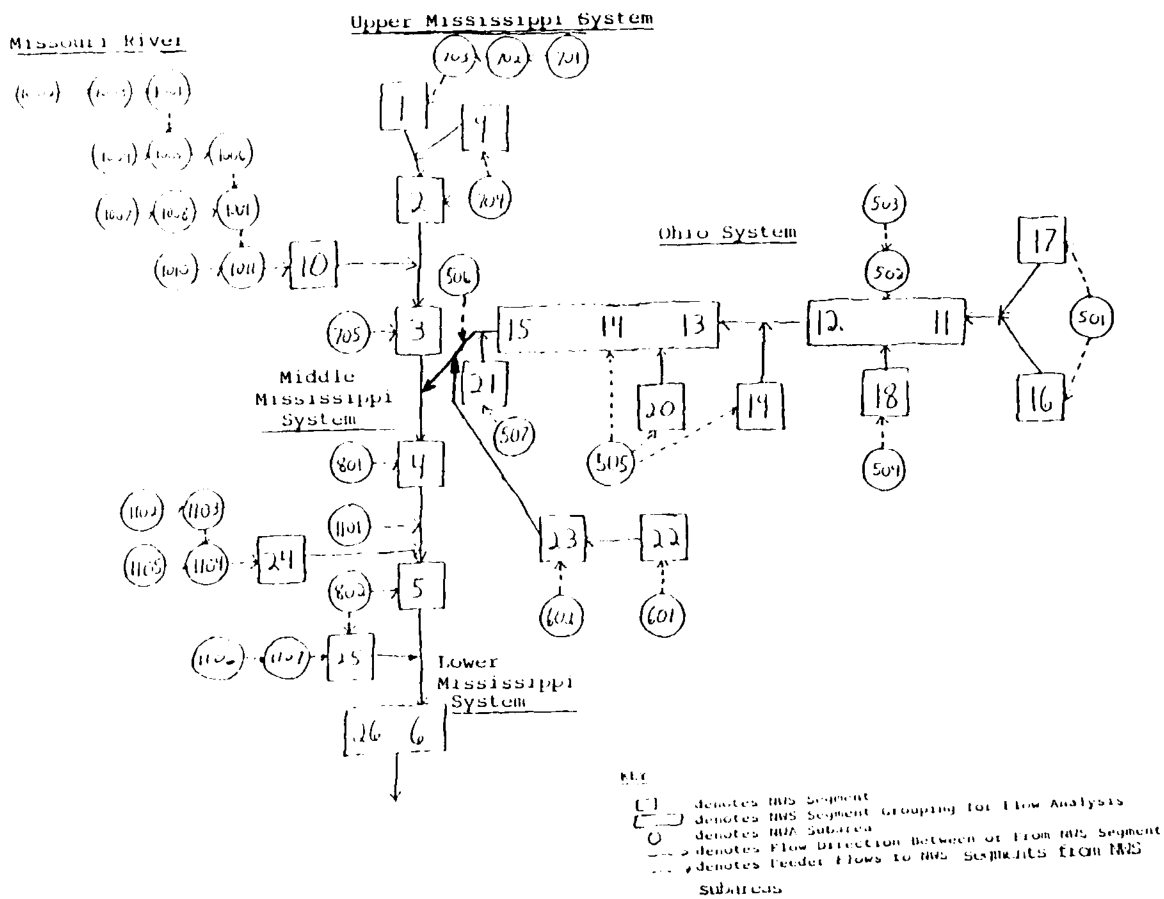
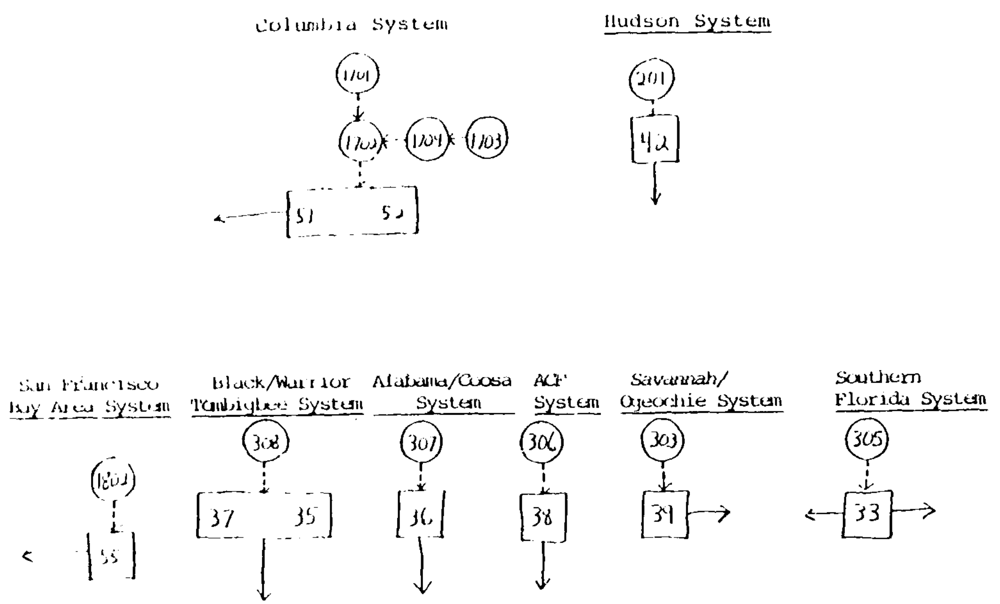


Figure III - B (cont'd)

Flow Systems for NWS Segments and NWA Subareas Analyzed



Key:
denotes NWS Segment
denotes NWS Segment Grouping for Flow Analysis
denotes NWA Subarea
denotes Flow Direction Between or From NWS Segments
denotes Feeder Flows to NWS Segments from NWA Subareas

water levels. The analysis for each segment includes a discussion of future trends which affect water availability, a discussion of the depth relationship to navigation, historic problems and Corps actions, flow management considerations, storage availability, and planning structure Corps control.

1. Water Budget. The water supply data used for this analysis comes principally from the NWA data used for the screening in step five, but they are presented on a monthly average basis. Water consumption estimates were also adjusted to monthly averages using the annual patterns established in the NWA for eight basic categories of water demand: domestic and commercial water supply, power plant cooling, synthetic fuel plant demands, mining demands, industrial demands, irrigation demands (average and dry years), livestock and other water demands.

The macro-economic differences between water demand by segment were dropped for this analysis for the drought scenario, because the maximum difference between these alternate futures amounted to 3% of the total for any of the selected segments. This difference is less than the margin of accuracy of the forecasts themselves. Therefore, only large projects should be used to differentiate alternative futures from a water demand perspective (e.g., irrigation projects and coal slurry pipelines).

2. Flow Management. Information on reservoir operations was obtained from analysis of reservoir operations manuals used by the Corps, and discussions with individuals in the Corps Districts, Water Basin Commissions and other Federal or State agencies. The date presented in this section relates primarily to the amount of control that is available for navigation during low-flow periods. More data for certain segments are provided in the following section of this report.

3. Navigation Needs and Relation to Depth. Navigation needs on the waterways have been defined as a flow regime that provides, at least, authorized dimensions for each segment, and provides a velocity range that permits safe maneuvering of vessels and tows. When flow deviates from these conditions, there is an observable impact on navigation. When flows are lower, waterway depths decrease and there is more risk of grounding. The carriers respond with light loading or shifts of their operations to areas where they can rely on adequate depth.

When flows are higher, river velocity limits tow maneuverability and carriers reduce tow size to give them a safe margin of power for maneuvers. At some point high water forces closure of a waterway segment to navigation, either through flooding out of locks, or because velocities become too dangerous for any size tow in some stretches.

Both of these types of flow impacts on navigation are discussed in this report with reference to each waterway segment where flow has been identified as a potential constraint. Depth to flow relationships on five free-flowing segments were developed through conversations with knowledgeable Corps personnel and waterway users.

4. <u>Relationship of channel depth to navigation</u>. The minimum channel depth that permits waterway shippers to operate is a function of a combination of factors. These factors may be categorized as constraints resulting from the towboat and barge characteristics, and those resulting from economic considerations.

The equipment characteristics which determine navigable depths include the drafts of towboats, drafts of barges, and to some extent the engine horsepower and number of engines in the towboat. The main economic factor is the carrier's perception of his marginal risks, costs and benefits. Some carriers will load more heavily than others for the same conditions if they are willing to take higher risks, or have better knowledge of river conditions.

The draft of towboats presently being used on the inland waterways is standardized at 8 1/2 feet, despite widely varying horsepower ratings which typically range from 4,500 HP up to 10,500 HP. There are exceptions to the 8 1/2 foot standard which occur on rivers that seasonally exhibit less than 9-foot depths, such as the Missouri and the Alabama Rivers. On these rivers towboats with drafts of 7 1/2 feet are more commonly employed. Drafts less than the above figures are found occasionally on towboats with very low horsepower ratings or boats that have been especially designed for local conditions.

For some soft-bottomed rivers, such as the Alabama and the ACF, navigation normally proceeds with frequent "touching of bottom" and drafts measured to the nearest inch become important. Compensation measures for such conditions include the use of triple screw boats to

increase thrust, shifting of ballast to improve the craft's stability, and reduction of fuel reserves to allow more clearance under low flow conditions.

The operating draft of a barge depends, of course, upon the extent to which it is loaded. The profit margins for more shippers require that barges be loaded as close to their capacity as possible. The costs of moving a barge loaded to nine feet, for example, are almost the same as for one loaded to 11 feet. Light loading because of restrictive channel depths is a common practice on many waterway segments at least part of the year. As a rule of thumb, six inches in draft is equal to 100 tons of cargo for a 35' x 195' barge.

The economic considerations involved in light loading are often commodity dependent. In many instances carriers apply a variable rate structure and quote higher rates for light loading conditions. This puts the decision in the hands of the shippers to determine if the increased costs for each specific commodity warrant transportation on the waterways. In some cases carriers may operate during low flows at a loss due to light loading in order to demonstrate the reliability of their service to their costumers. Obviously, the length of these operating periods is short and dictated by the overriding economic concerns of each carrier's and shipper's situtation.

Channel depths are a function of discharge, but this relationship is different during different seasons of the year. Rising or falling stages will often produce different depths for the same discharge. Sedimentation rates vary with several river characteristics, including discharge, and are site specific as to their effect on navigable depths. Thus, a rating curve which indicates the relationship between discharge and depth is only truly applicable for the stretch of river on which the gauge is located. However, most river segments have one gauging station that generally serves as an indicator of navigation conditions, and towboat operators generally depend upon the depth information obtained from these stations during low flow periods.

The impact of low flows and high flows on navigation is described in the following sections for the eight waterway segments identified as having potential low flow problems. This report does not deal with the problem of changing flow patterns and their effects on sediment

transport, except briefly for the Middle Mississippi, as this area was excluded from the NWS scope. In addition, the relatinoship of depth to dredging effort is not covered here, as this is examined in other NWS reports. The analysis in this report assumes that the present level of dredging effort is maintained.

ANALYSIS OF WATER AVAILABILITY

(a) Forecast Water Availability by Region

In order to select those NWS regions and segments which merited a detailed analysis, a simplified, second-level screening process was used. This process, which was described in the methodology section above, produced the date shown in Table III-4.

Canalized segments (i.e. slack water segments with locks and dams) were analyzed in a different manner from free-flowing segments. For canalized segments, the ratio of year 2000 streamflow less water consumption upstream and along the segment, to average navigation lockage water needs for the segment at present navigation levels, is used. This ratio, called the Navigation Need Satisfaction Ratio in Table III-4, shows that the Red River in Region 4 and the Arkansas Rivers in Region 10 would possibly experience water shortage problems serious enough to affect navigation, under the screening assumptions. All other canalized segments appear to have enough flow to provide lockage water for at least four times the present traffic levels, and in many cases more than 20 times these levels.

Free-flowing river stretches require much more water to maintain channel depths than canalized segments, and these stretches require a constant dredging effort to provide the authorized channel depth with present flow patterns. For these segments the screening measure used was a percent reduction in flow due to increased upstream water consumption form 1975 to 2000. This index, as shown in Table III-1 shows the impact on flow to be substantial for the Lower Upper Mississippi (Region 2) and the

Table III-4

Water Availability by Region for Commercial Navigation

A. Canalized Segments

WRC Region		WRC Segments	Condition	Worst-Month Data in Year 2000[1]: Total Stream Flow (MGD)	Worst-Month Data in Year 2000[1]: Stream Flow less Consumption (MGD)	Present Navigation Need[2] (MGD)	Navigation Need Satisfactory Ratio[3]
1	Upper Mississippi	1	Average	32,900	31,200	612	51
			Drought	14,100	13,200	612	20
2	Lower Upper Mississippi	2	Average	45,000	42,600	219	195
			Drought	23,400	20,700	219	94
4	Lower Mississippi	25	Average	16,900	15,600	12	1,299
		Red	Drought	1,300	*	12	-
5	Illinois River	9	Average	9,000	8,600	107	81
			Drought	6,900	4,400	107	40
7	Ohio River	11, 12	Average	17,200	14,900	507	29
		Ohio	Drought	6,100	3,800	507	7.5
		13, 14, 15	Average	17,200	14,400	540	27
		Ohio	Drought	6,100	3,300	540	6.1
		16	Average	3,300	2,200	128	17
		Monongahela	Drought	660	540	128	4.2
		17	Average	3,700	3,300	31	114
		Allegheny	Drought	1,100	900	31	28
		18	Average	3,100	2,800	109	26
			Drought	1,300	1,000	109	9.1
		20	Average	3,900	3,600	37	71
			Drought	850	580	37	61
		21	Average	14,800	14,600	180	81
			Drought	3,700	2,500	180	14
8	Tennessee River	22	Average	17,500	17,000	368	46
			Drought	13,200	11,700	368	32
		23	Average	25,700	24,900	300	83
			Drought	15,600	14,800	300	49
9	Arkansas River	24	Average	16,200	*	120	-
			Drought	7,800	*	120	-
10	Gulf Coast	28	Average	15,700	14,800	44	338
		ACF	Drought	9,700	8,700	44	199
12	Tombigbee-Alabama-Coosa-Black Warrior	25, 27	Average	6,800	6,400	192	33
			Drought	2,900	2,500	192	13
13	South Atlantic Coast	29	Average	6,400	6,200	34	181
			Drought	1,600	1,400	34	43
18	Columbia-Snake River	51, 52	Average	151,400	131,100	138	878
			Drought	112,200	60,800	138	394

B. Free-Flowing Segments

WRC Region		WRC Segments	Condition	Project Design Flow (MGD)	1975 Worst Month[1] Less Consumption Stream Flow (MGD)	Worst Month[2] 1975-2000 Upstream Consumption Increase (MGD)	Yr 2000 Flow Navigation Reductions from 1975 Levels[4]
2	Lower Upper Mississippi	3	Average	15,300	91,800	38,300	42%
			Drought		63,300	27,300	45%
3	Lower Mississippi	4	Average	97,000	178,000	31,300	17%
			Drought	97,300	125,300	31,300	18%
		5	Average	97,400	240,000	41,300	17%
			Drought	97,400	156,300	19,300	12%
		6, 26	Average	117,300	239,000	48,300	20%
			Drought	117,300	157,000	22,300	14%
4	Baton Rouge to Gulf	25	Average	1,500	6,900	3,300	43%
		Red	Drought	1,400	1,400	3,100	*
6	Missouri River	10	Average	21,400	35,400	28,300	79%
			Drought	21,400	16,600	29,300	*
11	Gulf Coast West	38	Average	6,300	15,300	530	3%
			Drought	6,300	4,300	500	12%
12	Tombigbee-Alabama-Coosa-Black-Warrior	26	Average	5,600	7,900	130	2%
		Alabama	Drought	5,600	1,300	130	1%
18	Columbia-Snake River	51, 52	Average	5,400	128,300	5,500	4%
			Drought	5,400	70,300	9,300	13%

*Projected demand in the basin is greater than average flow, assuming for screening purposes that groundwater mining is [illegible] and demand is not cut back.

NOTES:
1. The worst month is that for which the ratio of water supply to demand is lowest.
2. Defined as the flow needed for lockage water at the lock with highest lockage water requirements in the segment.
3. The ratio of column 5 to column 4.
4. Column 6 as a percent of column 5.

Missouri (Region 6) which shows the highest of the forecast reductions in flow availability. The Red River (Region 4) shows up again, as well. All of these segments were retested for further analysis.

The Columbia River shows a potential impact in future drought periods, but still with high flow levels. Therefore, it did not merit further analysis in this section.

The Lower Mississippi shows a relatively moderate impact (10-20% under screening assumptions). This is a marginal case, so only one segment (4) was selected for further analysis.

Although the Alabama-Coosa in Region 12 and ACF in Region 10 do not require further analysis based on future water consumption changes, it was decided to provide further details on their water availability due to the presence of existing problems with water availability for navigation. In addition, some analysis of Great Lakes water availability was included due to the uncertainty about the effects of future water consumption on water levels for their navigation channels.

(b) Water Consumption Characteristics

In the course of the above screening analysis two other types of information were obtained which shed some light on present and future water consumption characteristics. First, it is apparent that the principal factor affecting future water consumption is irrigation. An increase in irrigation water demand on surface water is expected to come from the states west of the Mississippi. This increase is somewhat unpredictable due to the unknown reactions of farmers and water planning agencies to future reductions in groundwater levels due to groundwater mining. However, this increase does imply greater seasonal differences in water demand as irrigation use peaks in July and August. Table III-5 shows these peaking patterns in the "worst month."

Table III-5

Worst Month Relation to Average Month* Water Consumption by Segment

NWS Region	NWS Segment	NWA Subareas	Average Year Month[2]	Average Year Ratio[3]	Dry Year[4] Month[2]	Dry Year[4] Ratio[3]
1. Upper Mississippi	1	703	August	1.457	August	1.540
2. Lower Upper Mississippi	2	704	August	1.442	August	1.519
	3	705*	August	3.186	August	3.232
3. Lower Mississippi	4 (less 1101 and 1104)	801*	August	2.971	August	3.041
	5 (less 1107)	802*	August	2.928	August	2.996
	6, 26	802*	August	2.928	August	2.996
4. Baton Rouge to Gulf	25 (Red)	802*	August	2.433	August	2.514
5. Illinois	9	704	August	1.412	August	1.476
6. Missouri River	10	1011*	August	3.428	August	3.449
7. Ohio River	11, 12	502	September	0.999	September	0.993
	13, 14, 15	505 (less 506, 507, 602)	September	0.979	September	0.976
	16	501	September	1.038	September	1.038
	17	501	September	1.038	September	1.038
	18	504	September	1.028	September	1.021
	20	505	October	0.930	October	0.924
	21	507	June	1.049	September	0.981
8. Tennessee River	22	601	June	1.018	July	1.056
	23	602	October	0.972	September	1.008
9. Arkansas River	24	1104*	August	3.594	August	3.619
11. Gulf Coast East	38	306	June	1.735	June	1.787
12. Tombigbee Alabama-Coosa-Black Warrior	35, 37	306	September	0.998	September	0.995
	36	307	October	1.006	October	1.083
13. South Atlantic Coast	39	303	June	1.225	October	0.931
18. Columbia-Snake River	51, 52	1702[5]	August	2.478	July	3.329

NOTES:

*A more detailed explanation of the analysis is provided in Appendix A.

1. In addition to the adjacent subarea shown, all upstream subarea consumption, if any, is taken into account.
2. Month selected for the lowest ratio of supply to demand.
3. Ratio of worst month consumption to average month consumption.
4. Year with flows at the 95% exceedence levels in the selected month.
5. High irrigation use with summer peaks.

Table III-6

Year 2000 Differences in Water Demand by Macroeconomic Forecast
(average (MGD) long and upstream of segment)

	NWS Region	NWS Segment	Base	FORECAST LARGEGOVT Total	LARGEGOVT % Base	LESSGOVT Total	LESSGOVT % Base	BADENERGY Total	BADENERGY % Base
1.	Upper Mississippi	1	1,157	1,147	99	1,157	100	1,142	99
2.	Lower Upper Mississippi	2	1,668	1,650	99	1,663	100	1,644	98
		3	25,820	26,336	102	25,241	98	25,232	98
3.	Lower Mississippi	4	27,659	28,173	102	27,080	98	25,069	98
		5	34,995	35,492	101	34,409	99	34,229	98
		6, 26	38,511	39,000	101	37,925	99	37,662	98
4.	Baton Rouge to Gulf	25 (Red)	2,377	2,373	100	2,377	100	2,317	97
5.	Illinois River	9	297	292	98	294	99	292	98
6.	Missouri	10	20,344	20,910	103	19,771	97	19,816	97
7.	Ohio River	11, 12	2,336	2,324	100	2,335	100	2,317	99
		13, 14, 15	2,889	2,868	99	2,388	100	2,862	99
		16	112	114	102	112	100	110	98
		17	179	179	100	179	100	176	98
		18	278	275	99	278	100	275	99
		20	282	277	98	282	100	278	99
		21	158	155	98	158	100	156	99
8.	Tennessee River	22	486	484	100	486	100	485	100
		23	815	809	99	815	100	811	100
9.	Arkansas	24	5,783	5,776	100	5,776	100	5,634	98
11.	Gulf Coast East	38 (ACF)	530	526	99	530	100	521	98
12.	Tombigbee-Alabama-Coosa-Black-Warrior	35, 37	437	436	100	437	100	436	100
		36	430	397	99	403	100	398	99
13.	South Atlantic Coast	39	196	196	100	197	100	195	100
18.	Columbia-Snake Rivers	51, 52	2,230	12,227	100	12,230	100	2,210	100
	Average % (all segments)	-	-	-	100	-	100		99

The second type of information gained during the screening analysis concerned the insensitivity of water demand projections on the segment level to alternative assumptions embodied in the NWS economic forecasts. In addition, to a base forecast which continues present trends, three other macro-economic forecasts were examined for their impact on future water consumption. These were: two forecasts which assume a lesser or greater level of government spending in the economy (called LESSGOVT AND LARGERGOVT) and a forecast assuming higher energy prices than the base case (BADENERGY).

The impact of different levels of government spending have no consistent effect on all segments. They increase future consumption on some segments and decrease it on others, as shown in Table III-6. Higher energy prices, on the other hand generally decrease future water consumption, but not to a significant degree. None of the differences in macro-economic forecasts changed water consumption on any segment more than 3% up or down relative to the base case.

DETAILED ANALYSIS OF SELECTED SEGMENTS

Based on the water availability analysis above, segments in seven regions were analyzed in greater detail. These were: Lower Mississippi (Missouri to Cairo, Illinois), Lower Mississippi (Cairo to White River), Baton Rouge to Gulf (Red and Ouachita Rivers), Missouri River, Arkansas River, Gulf Coast East (ACF Rivers), and the Tombigbee Alabama-Coosa-Black Warrior river systems. In addition, the Great Lakes segments were examined for the long-term effects of future water consumption on lake levels.

Each section contains a discussion of the monthly water budget in 1975 and 2000, the effects of future water use technology trends, navigation needs and problems, flow management considerations, storage availability and planning structure. The conclusions in each case identify those segments where flow effects are forecast to be a problem for navigation on an annual basis, and those segments where other factors intervene to prevent flow problems from affecting commercial navigation.

(a) Regions 2 and 3: Middle Mississippi River

The two regions on the Mississippi were combined in this analysis since the segments they contain have related characteristics and problems. These are Segment three, from the Missouri to Cairo, and Segment four from Cairo to the White River.

1. Present Water Supply. The existing supply of water for these two segments for average and drought occurrences is summarized in Table A-15, Appendix A for 1975 levels of development. For Segment 3, average annual flow (121,000 MGD) is about 185% of drought flow. The ratio between the maximum month and the minimum is 300% for an average year and 302% for a drought year. In Segment four, the average annual flow (302,000 MGD) is 214% of drought annual flow. The maximum month is 397% of the minimum month in an average year and 339% in a drought year.

These segments receive large amounts of water from other major water basins. Flow on Segment three emanates from the Missouri, Upper Mississippi, and Illinois Rivers. Flow on Segment four primarily originates from Segment three and the Ohio River system. Due to these dependencies, it is important to stress that flow problems or water shortages on tributary sgements are likely to be the cause of problems on these Middle Mississippi segments.

2. Present and Future Water Demands. Monthly water consumption, by use, for the two segments is also given in Appendix A (Tables A-16 and A-17). The values in the tables are cumulative and therefore include all consumption in and above each segment. Variations between average and dry years are shown for irrigation. The other uses are not significantly affected by drought.

The most significant category of water consumption affecting Segments three and four is upstream irrigation activity, particularly in the Missouri River Basin. For Segment three in the year 2000 water for irrigation may be responsible for approximately 70% of all consumption along or above the segment in an average year, and 73% of all consumption in a dry year. The respective

numbers for Segment four are 71% and 74%. While these percentages with year 1975 irrigation is projected to be the use requiring the largest average daily increase in consumption. In Segment three, this increase exceeds four billion gallons a day in an average year and approaches five billion gallons a day in a dry year. Increases for Segment four are approximately five to ten percent higher. These projected increases alone represent an amount of water far larger than total projected requirements for the next largest use, industrial purposes.

For both segments in the year 2000, industrial uses are projected to be responsible for roughly 11% of an average year consumption total. Similar water consumption numbers for remaining categories are as follows: power plant cooling, 7%; domestic and commercial, 5%; livestock, 4%; minerals, synfuel, and "other", 2% or less.

Dry year projections for Segments three and four exaggerate projected water consumption, as it has been assumed that the drought is occuring along all tributaries simultaneously. In reality, this is a highly unlikely event, as indicated by historical information. Shortages of flow from one major tributary are usually compensated by higher than normal flows from another, allowing the Middle Mississippi area to maintain navigation activity.

Irrigation technology is obviously of key importance to water consumption affecting flows on Segments three and four. Since irrigation activity is primarily occurring in the Missouri River Basin, a discussion of research and development for irrigation is included in the Segment 10 discussion of this report. Briefly summarizing the discussion within the Segment 10 section, there is no reason to believe that new irrigation technology will be utilized to significantly decrease water consumption by the year 2000. The present focus of research and development, present water allocation, and institutional barriers allow little reason to believe that there will be any effective effort to develop and implement systems consuming less water.

3. Future Water Availability. The impact upon streamflow of increasing water consumption is shown in Figures III-C and III-D. The figures are graphs of monthly streamflow for average and drought years under 1975 water consumption levels and 2000 water consumption levels. On Segment three, the increase in annual water

consumption from 1975 to 2000 is 6% of annual average flow and 13% of annual drought flow. The largest monthly increase in water consumption is 23% in an average year and 44% in a drought year. On Segment four, the increase in annual water consumption is 3% of annual average flow and 6% of annual drought flow. The largest monthly increase in an average year is 13%. In a drought year the largest monthly increase is 27%.

4. Depth Relationships to Navigation. The Middle Mississippi River (Segment three) exhibits a wide range of both river conditions and size of towboats and barges that navigate on the river. Towboats normally have an eight and one-half foot draft and barges are light loaded during low flow conditions to as close to the minimum water depth as the shipping firm is willing to risk. Rock bottoms along certain stretches also limit channel depths and increase the risk factors. One operator incidated that channel depths less than 10 feet constrained their operations. (The increased risk of grounding causes them to load some barges lighter than they otherwise would.)

The Middle Mississippi River between St. Louis and Cairo is subject to low flows which annually approach the nine foot authorized depth. There are more than 20 crossings on this river segment that annually are dredged to maintain the authorized channel dimensions. Occasionally, extreme low flows have required narrowing of the channel width in order to maintain the authorized channel dimensions. Occasionally, extreme low flows have required narrowing of the channel width in order to maintain the nine foot channel depth. In 1977, the channel width was reduced to 175 feet from its authorized width of 300 feet during a short period of time at several points along the river. Discharge fell to 50,000 cfs during this low flow period. As tows are frequently 108 feet wide along the Middle Mississippi these narrow channels caused delays to river traffic.

High flows have had only a small effect on navigation along the Middle Mississippi River. Even during extreme overbank flooding, such as occurred in 1973, navigation has continued with little interruption. High stages have sometimes flooded locks and dams on tributary rivers which has reduced traffic on the Mississippi. High velocities reduce travel times for downstream craft and increase it for upstream directions. The highest velocities

FIGURE III-C

Middle Mississippi, Stream Flow Data

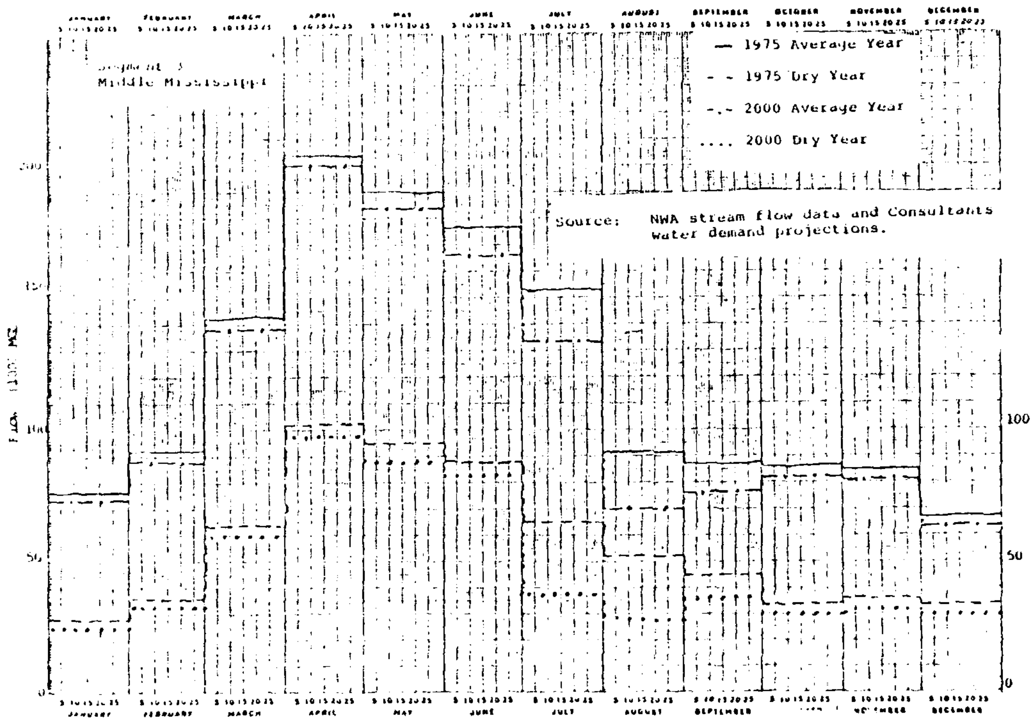
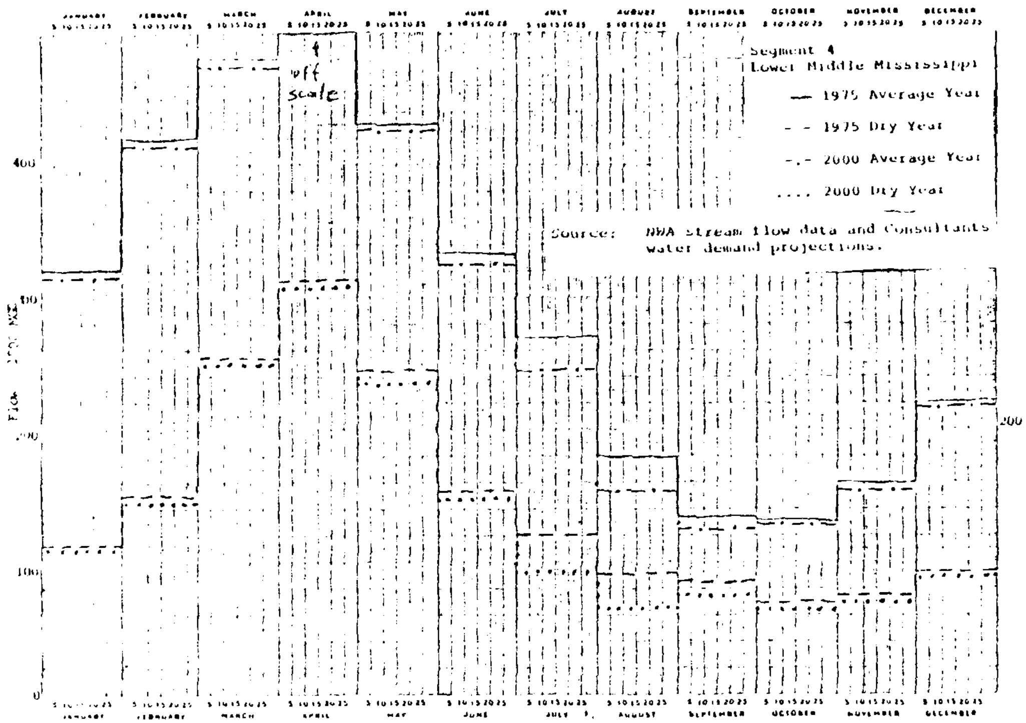


FIGURE III-D

Lower Middle Mississippi, Stream Flow Data



result from flood conditions which occur only infrequently. Under such conditions a small percentage of operators with low powered boats may discontinue operations entirely. Flood flows, on balance, are favorable to navigation in the Middle Mississippi as barges are loaded to capacity and the increase channel area allows for better boat maneuverability.

Boat operators consider the stage at St. Louis to be the representative depth for the Middle Mississippi segment. The depth discharge relationship provided by the Corps for low flow conditions at this group is given below.

Depth (feet)	Discharge (cfs)	(MGD)
10	70,000	45,450
9	63,000	40,900
8.5	59,500	38,600
8.0	56,000	36,360
7.5	53,000	34,400
7.0	50,000	32,470

The Lower Middle Mississippi River (Segment four) is comparable to the Middle Mississippi segment in the type of boats and barges in operation. The eight and one-half foot draft of towboats is the limiting depth. Discharges, however, are about three times those of the Ohio River below Cairo. Nevertheless, maintaining a minimum nine foot channel requires extensive dredging within the Memphis District primarily during the post flood season of summer and early fall. An indication of channel depths is given in the accompanying graph, "Baton Rouge to Cairo, Duration of Depth." It can be seen that depths below 10 feet may occur any time during the year but are most prevalent in August and September.

Dredging is required to maintain authorized depths over a period of time that normally lasts from June through October. During this period river discharge and stage are descending and sedimentation is occurring. The rates and locations of shoaling vary considerably although there are three to four specific crossings that annually become trouble spots and may require dredging four to five times a year. Dredging usually begins in the Memphis District when a stage of ten feet, corresponding to a discharge of 415,000 cfs, is reached. Dredging continues until the low water period of October through December is

reached. During these latter months, little dredging is performed as the combination of low sediment load and low flows produces conditions whereby the river maintains or even improves the channel dimensions because of scour (see Element K report for more detail). The authorized depth and width have reportedly been maintained at the record low flow level of 135,000 cfs (-5 at St. Louis gauge). In consideration of the extreme range of flow conditions, corresponding depth, and required dredging volumes on the Lower Middle Mississippi, a relation between depth and discharge has little validity.

5. Historic Problems for Navigation and Corps Actions. In the first two months of 1977, extreme cold in combination with low flows caused cessation of navigation on the Middle Mississippi due to ice flows and ice jams. Studies were undertaken to assess how flow augmentation could be utilized to reduce ice problems. The results indicated that it is extremely difficult to use reservoir releases for this purpose on the Middle Mississippi, as problems must be forecast well in advance due to the long travel time of releases from distant reservoirs. Potential releases are also limited due to downstream flooding considerations. During other low flow periods on the Middle Mississippi the channel width over which adequate depth exists has been reduced (e.g. 1976).

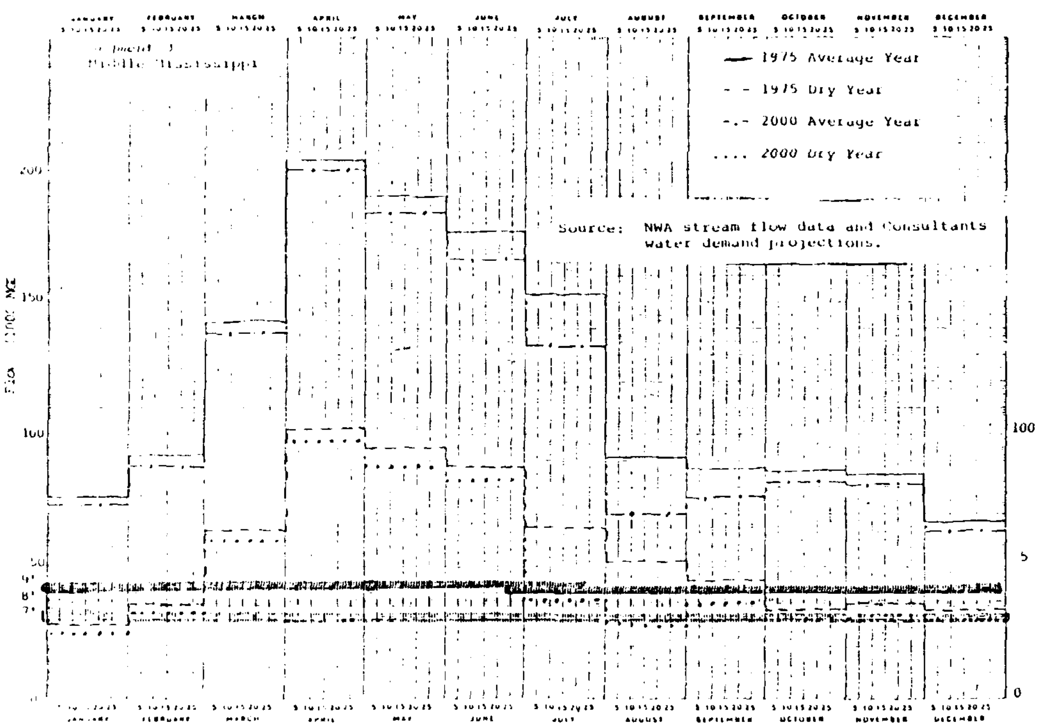
Corps actions on these segments have traditionally consisted of dredging and river maintenance activity. Reservoir operation has not been used specifically to augment flows in the Mississippi River.

6. Future Navigation Flow Problems. Navigation flow problems on the Middle Mississippi are difficult to predict due to the very complicated relationship between flow and depth. On Segment three this relationship appears to be more direct and a graph of future flows, with channel depths included, is shown in Figure III-E. No problems exist or are expected in the future during average flow years. However, as experienced in the past, under drought situations there will be insufficient flow to maintain authorized channel dimensions. There are approximately five critical months under present conditions and this is expected to increase to eight months by 2000.

Depth constraints on Segment four are related less to absolute flow and more to the rate of change of flow. During the spring and early summer when flows are

FIGURE III-E

Middle Mississippi, Low Flow and Depth Relationship



rising or high there are usually no problems with depth. In the late summer and early fall as flows are falling and can no longer maintain the sediment load, shoals develop which constrain navigation and require dredging. In the late fall and winter when flows and sediment loads are low the river remains in the main channel which it then scours so that authorized dimensions are maintained. The problems occur during falling discharges with high sediment loads. The duration of controlling depths of 10 feet and 12 feet or more in the stretch from Cairo to Baton Rouge is provided for the last 19 years in Figure III-F to illustrate the situation. (More information is provided in the Element K report.)

The effects of increasing water consumption on this complex relationship are difficult to predict. If flows are reduced and become more constant, there could be fewer problem areas and less need for dredging. However, increases in water consumption will be greatest in the late summer due to irrigation extremes. The most likely future change, however, would be a slight shift of depth problems from August to July, as decreased July flows affect flood recession rates. Otherwise, the navigation problems will remain essentially unchanged.

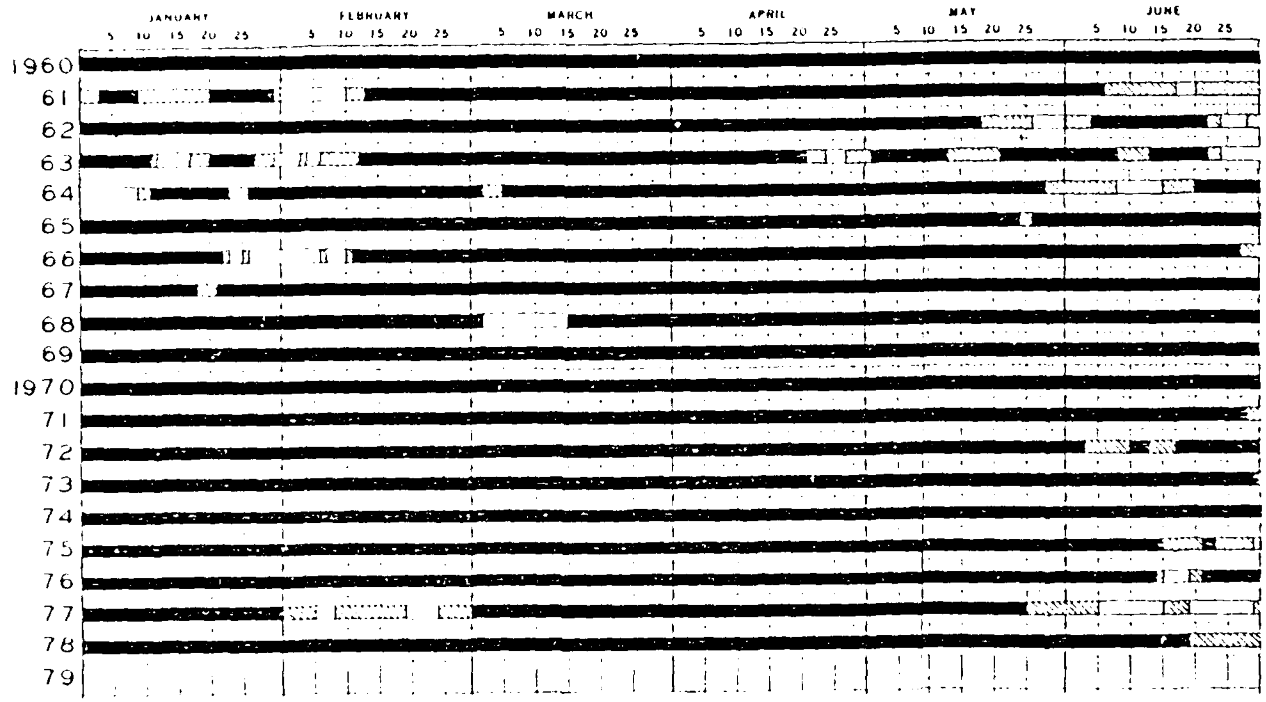
7. Relationship to Reservoir Releases. The Corps presently maintains the nine foot channel along the Middle Mississippi primarily through dredging and river training structures. Reservoirs augment Mississippi River flows although they have not been utilized due to the time of travel and their small size in relation to the the Mississippi River.

8. Storage Availability and Reservoir Releases. Reservoir operations have the capability for short-term assistance of navigation activity on the Middle Mississippi segments. The Clarence Cannon Project under construction on the Salt River is authorized to support flood control, hydropower, navigation and recreation activity. The flood control pool will be capable of holding 971,000 acre-feet of storage, while a joint-use pool will have capacity for another 457,000 acre-feet. This project is scheduled for completion around 1981 or 1982.

The Carlyle and Shelbyville Projects hold storage for the Kaskaskia River, which allows navigation to the Mississippi River. These projects are authorized for flood control, navigation, water supply, and recreation.

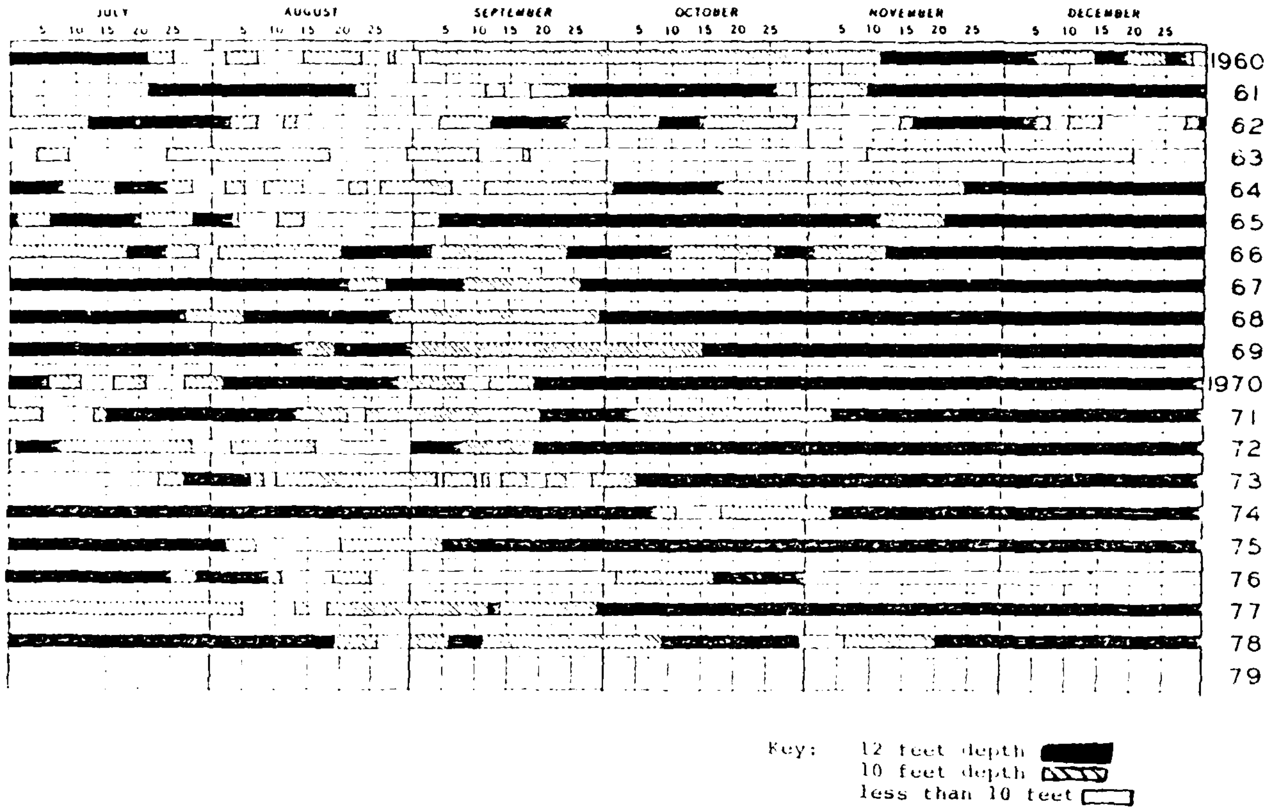
FIGURE III-F

Duration of Controling River Depths
Baton Rouge to Cairo (Preliminary)



Key: 12 feet depth
10 feet depth
less than 10 feet

FIGURE III-F (Continued)



Combined storage in these projects is 1,667,000 acre-feet, with 1,254,000 acre-feet allocated to flood control and 413,000 acre-feet allocated for joint-use among other authorized projects. However, minimum monthly flows in Segment three during a drought average over 10,000 acre-feet per day. Obviously, this storage is not sufficient to augment any long term low flows.

9. Planning Structure and Corps Control. Water flow planning has not been a major concern for the Corps on the Middle Mississippi, as dredging and other maintenance activity is the primary response to the immediate needs of navigation. It is difficult to correlate flow decreases with increased dredging activity, as location and extent of the activity is constantly changing. When flow drops to the point where dredging expense is beginning to increase, more analyses will be conducted to assess the economics of maintaining various depths and alternative solutions.

Reservoir operation will be modified on the basis of case by case problems. Water supply and navigation on the Kaskaskia are considered very important and would receive higher priority, but all uses would be considered in the event of a severe shortage.

10. Relative Influence and Impacts of Non-Navigation Uses. Since reservoir releases for projects on tributaries to the Middle Mississippi come from joint-use pools, competition between uses exists. To date, conflicts have not been a problem and interest group pressures have not been a major concern. However, the local reservoirs have not been drawn down to assist navigation.

The Carlyle and Shelbyville Projects have drawn substantial recreation investments from both private and public sources, and Cannon is also expected to be a significant recreation area. For the first two projects, drawing the joint-use pool down has substantial adverse impact upon recreation activity. Coves holding boats and launching ramps are often in depths of only six to seven feet, and drawing the joint-use pool down to support navigation could cause significant problems for recreation users.

Recreation users are very vocal, and past drawdowns have led to strong protest. In the summer, a drawdown to support Mississippi River navigation would result

in severe financial costs for concessionaires. Thus, there may be serious questions pertaining to whether or not these res 'oirs can actually use the joint-pool for Mississippi l flow augmentation.

Othei technological development is expected to have minima impact upon Middle Mississippi segments, as changes in ɛ iciency within categories other than irrigation will nc significantly impact total consumption.

11. <u>Conclusions</u>. The types of problems likely to be encountered on the Middle Mississippi in the next 20 years are the same as those presently occurring. The magnitude of these constraints is difficult to project since increases in water consumption could intensify or reduce these conflicts.

Water demand management for upstream areas could have minor effects on base flows in the Middle Mississippi. Increasing irrigaton efficiency in the Missouri River Basin could boost potential flows a small amount. For example, a two percent increase in irrigation efficiency will increase flow by approximately 370 MGD for an average day in the year 2000, assuming all water not consumed due to efficiency increases reaches downstream segments.

Interbasin transfers and reservoir operation are less likely strategy measures. Interbasis transfers are simply not being considered due to the vast distance to other water sources and the vary large amounts of water necessary.

Reservoir operation has some potential to assist in short-term low flow augmentation, bu competition from other uses makes this a potentially difficult option. The usefulness of this action is severly limited by the small size of nearby reservoirs or the distance to large reservoirs.

Louis Berger and Associates has concluded that construction of new reservoirs is not politically or institutionally feasible at the present time, and it is doubtful that navigation benefits would be substantial enough to make new projects feasible. Political trends, including new emphasis upon tax cuts, fiscal restraint, and benefit-cost reassessments, contribute to the difficulty of justifying these proposals.

12. Critical Factors and Data Gaps. The most important consideration to navigation on the Middle Mississipppi is the relationship between depth, discharge and rate of change of discharge. How that relationship will be modified by increased water consumption is not known but should be the subject of additional study.

(b) Region 4:
Baton Rouge to
Gulf

The tributaries to the Mississippi in this region are the only waterways identified with potential low flow problems. These are the Ouachita-Black and Red Rivers, both of which are relatively new systems and, in the case of the Red, still incomplete. Both are analyzed below.

1. Present Water Supply. Streamflows in the Ouachita River, for an average year and a dry year, under 1975 conditions are shown in Appendix A, Table A-15. Average flows on the Ouachita during a drought (167 MGD) are less than two percent of average streamflows (125,500 MGD). Drought flows on the Red River (6,500 MGD) average one third of normal flows (20,000 MGD).

2. Present and Future Water Demand. The most significant categories of water consumption affecting the Ouachita-Black Basin are irrigation and industrial uses. In the year 2000, irrigation is expected to be responsible for 52% of all water consumption in the Ouachita Basin in an average year, and 56% in a dry year. Industrial uses are projected to account for 28% of the total in an average year, and 26% in a dry year. In 1975, irrigation accounted for 74% of total consumption in an average year and 79% in a dry year. Comparable 1975 figures for industrial uses are 10% and 9%, respectively (See Appendix A, Table A-21).

Other categories of projected consumption and year 2000 share are as follows: domestic and commercial, nine percent in an averaje year and seven percent in a dry year; minerals, livestock, synthetic fuels and "other," less than three percent for all categories combined under average or dry conditions.

Almost all irrigation on the Oauchita-Black system occurs south of Monroe, Louisiana. This irrigation

activity utilizes groundwater sources. It is unlikely that there will be any significant transfer to direct tapping of tributary of mainstream sources. Some impact of continued groundwater mining may be reflected in mainstream flows, but this relationshp has not been determined.

Industrial uses are the category of the greatest expected growth in water consumption in the Ouachita-Black Basin. In the upper reaches of the basin, water for industry is used primarily for the processing of paper products, including extensive operations of the Georgia Pacific Company. Lower portions consume industrial water primarily for petroleum products and chemicals processing. The emphasis for process choice in these industries will be on minimizing energy costs, and while water withdrawals may be reduced significantly, it is doubtful that water consumption will decrease enough to significantly reduce total industrial consumption.

Present and forecast consumptive water demand in the Red River Basin, disaggregated by use, is shown in Appendix A, A-20. Irrigation consumption is tabulated for average and drought conditions. The other water uses do not vary significantly with available water.

The most significant category of water consumption affecting the Red Basin is irrigation. In the year 2000, irrigation is projected to be responsible for 81% of all water consumption in the basin an average year and 83% of all consumption in a dry year. Comparable numbers for 1975 actual consumption are 88% and 89%. The next largest projected water consumption is for the year 2000 for industrial, domestic, and commercial needs, each with a requirement for five percent of total consumption in an average year and four percent in a dry year. Power plant cooling, minerals and livestock will require approximately three percent of the total for each category in the year 2000, and synthetic fuel development uses are negligible.

In the Red River Basin wtaer availability is highly constrained, and forecasts are that water consumption for irrigation will slightly decrease from years 1975 to 2000. The highest growth will come from power plant cooling (54 MGD) and industrial needs (+63 MGD); however, growth in each of these categories is only a minor percentage of overall use in the basin.

The situation in the Red River Basis is similar to the Missouri River Basin (Region 6) and the Arkansas Basin (Region 9). At the present there is limited concern by upstream users of water in the Red River as it impacts the available water downstream. Water withdrawals and not consumption are the measure for allocation, and concern is more oriented toward enhancing access to water supplies than to increasing the efficiency of use.

Municipal withdrawals could have measurable impact upon supplies to the Red River reservoirs. Atoka Lake on Boggy Creek, a tributary of the Red River, is a major source of water supply for Oklahoma City, which is approximately 70 miles to the north. Discharges are then deposited into the Arkansas system resulting in an inter-basin transfer of water. Growing water supply requirements of Oklahoma City could be detrimental to downstream Red River flows if this same source continued to be utilized.

3. Future Water Availability. The impact upon streamflows of increasing water consumption for the Ouachita during a dry year is shown in Figure III-G. The impact during an average year is small and it is not included in the figure. However, in a drought, consumption is forecast to exceed available streamflow in seven months. These values do not include the effects of specific reservoir releases for the purpose of flow augmentation.

The impact on streamflow of future levels of water consumption during a drought year is shown in Figure III-H. For the Red River average year streamflows are not predicted to change significantly. On an annual basis drought year consumption will not change. However, increased peaking by irrigation users will decrease streamflow by a maximum of 33% in July while other months will have greater streamflow.

4. Depth Relationships to Navigation. The Ouachita River is maintained as a slack water pool from Jonesville Lock and Dam to Arkadelphia Arkansas.

Below Jonesville the river is, in theory free flowing and was identified as a potential low flow problem area. However, backwater conditions are created below Jonesville due to flow from the Mississippi River into the Atchafalaya Rier, which is regulated by the Old River

Figure III-G

Ouachita River, Stream Flow Data

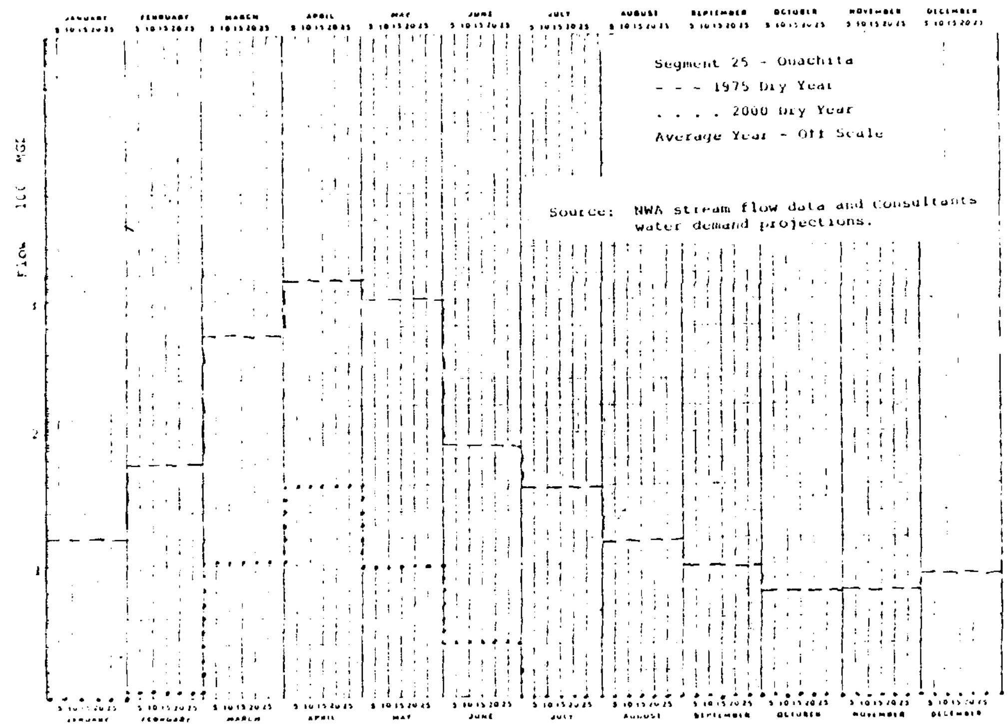
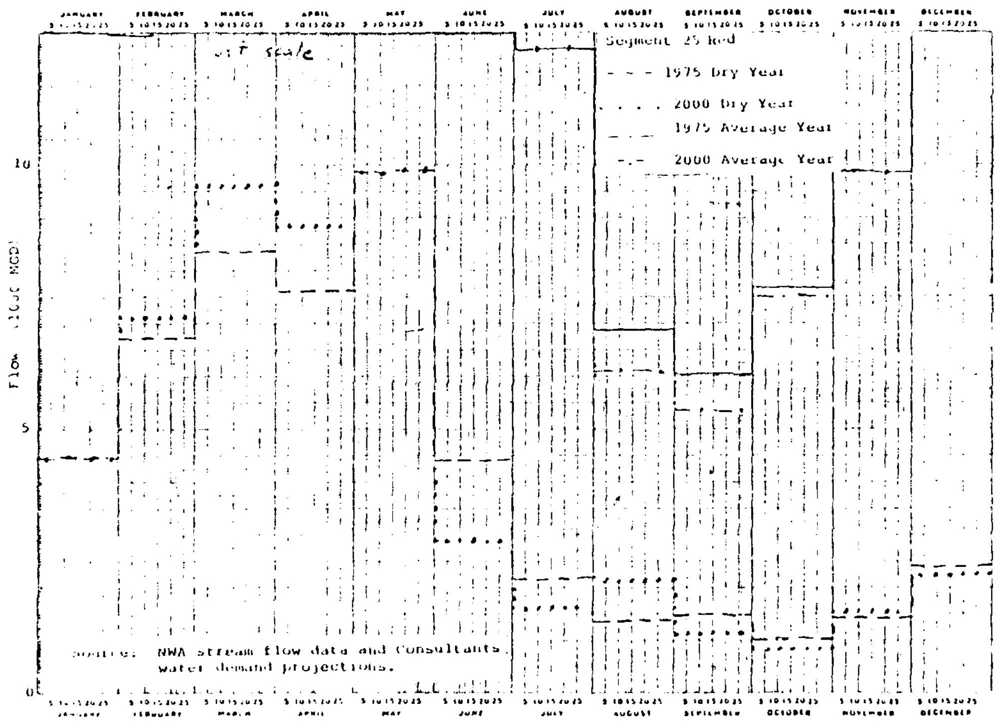


Figure III-H

Red River, Stream Flow Data



Control Structure on a daily basis. Historically, there has always been a flow below Jonesville although significant volumes of dredging are necessary to meet channel requirements. Mitigating effects of the Red River project when completed and the future operation of the Old River Control Structure, which is under study, both introduce unknowns which complicate the situation. The complexity of the hydrological conditions do not permit a meaningful depth-discharge relation to be developed and further studies are necessary as reduced flows are thought to be detrimental to navigation. Flood flows have never produced navigation probems on the Ouachita.

Dredging is necessary, however, to maintain channel depth, primarily because of sedimentation from the Red River. Shipping firms have confirmed that channel depths on the lower half of the Oauchita River are sufficient for eight and one-half foot draft boats that normally navigate the Mississippi River.

The Red River is presently undergoing a reevaluation of the location of the proposed lock and dams with the possible incorporation of hydropower facilities. The simultation of historic flows assuming completion of the proposed project conditions will pose a problem to navigation. However, until the lock and dams are in place and the question of whether hydropower will be a part of the project purpose is resolved, it is not possible to evaluate the effect on navigation of reduced flows.

Under present conditions the Red River is navigable on reliable basis only under high flow conditions which is about five months per year according to shipping interests.

The Red River carries a high concentration of sediment and requires extensive dredging along its lower reaches and below its confluence with the Black River in order to maintain the nine foot channel.

5. Historic Problems for Navigation and Corps Actions. Some problems for navigation have arisen where the river narrows and sharply bends. There has been concern about tows from opposite directions passing safely, and while radioed warnings are some help, the Corps has proposed construction of cut-offs. Some resistance in attaining rights for this construction has come from the

State of Louisiana, and to date no definitive decisions have been made concerning these proposed projects.

The upgraded nine foot depth Ouachita-Black system has two locks and dams in place, and two more are under construction. These projects are designed to assist navigation through allowing a channel of nine-foot depth to Camden, Arkansas. No hydropower capacity was installed. Completion of the last two projects will raise channel depth from six and one-half feet to nine feet in upper areas, and navigation activity on the system is expected to increase markedly in a short period of time. Navigation depth from Camden to Arkadelphia will remain at six and one-half feet.

Since low flows have not been a historical problem and the system is being modified and reevaluated, past Corps actions are not significant for judging possible strategies for future conflict resolution. The same is true for the Red River system.

6. Future Navigation Flow Problems. Because the Ouachita and the Red are designed to be fully canalized segments, water requirements for navigation are small. At present traffic levels only 12 MGD are needed for navigation and a simliar order ofmagnitude would be required to support traffic on the Red. However, during a drought situation consumptive water demand is forecast to exceed available supply. Under this scenario, competition for water will be intense. It is expected that the navigation requirement could be supplied from local reservoirs, but there will be pressure from all water users to gain access to any multipurpose storage. Without specific allocations, navigation will have to compete with other water uses for available storage and until releases, particularly of locks and dams, are fitted with hydropower generators. Nevertheless, the small relative size of navigation lockage demands would make the problem less signficiant.

7. Reservoir System. Three Corps-constructed projects, Lake Ouachita, DeGray Lake, and Lake Greeson hold storage for the Ouachita system. Ouachita and DeGray were constructed as features of the Ouachita River and Tributaries Project, and Greeson was constructed as a feature of the Little Missouri River and Tributaries Project. The Red River navigation channel is supported by

twenty reservoirs, most of which are located in tributaries to the north. Five locks and dams are being constructed between Old River and Shreveport, which enable a channel of nine foot depth to be opened.

No storage other than for navigation is planned behind any of these locks and dams, but economic feasibility studies are being conducted to see if hydropower facilities should be included. Preliminary indications are that the three locks and dams furthest downstream may be feasible for hydropower facilities, but only if energy prices continue to rise rapidly.

The master plan for the Red River system has not been completed, but upstream storage priorities are assumed to continue present operations. Current priorities for the Red River are:

(a) Flood control. All system reservoirs have a flood control pool already established.

(b) Hydropower. Rising energy prices will make this use a high priority, although few reservoirs contain hydropower facilities.

(c) Navigation. Projected navigation needs for lockage, evaporation, and depth requirements will be 1,056 cfs for traffic in the year 2000.

(d) Water Quality. This is a serious concern on the Red River, and constant reservoir releases can help alleviate problems.

(e) Recreation. A considerable investment is being made to develop this activity on the Red River system.

For the Ouachita, the priorities:

(a) Flood control. All lakes have flood control pools set aside to reduce downstream flood peaks.

(b) Power generation. All lakes have power pools set aside, and this purpose has the largest allocations.

(c) Water supply. DeGray Lake has an allocation for water supply, which is shared with the power pool.

(d) Navigation. No allocation is specifically given to this purpose, but DeGray Lake maintains constant releases, which assists shipping.

(e) Recreation. While not originally authorized, recreational development is extensive and given much consideration.

(f) Fish and Wildlife. No legal requirements exist concerning releases for this purpose, but guidelines presently are utilized. DeGray Lake has selective withdrawal capacity, and the outlet works in the dam include portals to withdraw water from three different elevations in the lake to provide water temperatures beneficial to fish in the downstream portion of the river.

(g) Water Quality. While not legally required, DeGray Lake makes releases for this purpose.

8. Storage Availability. Total reservoir storage capacity in the Ouachita Basin is 4,057,800 acre-feet of which 972,400 acre-feet are reserved for flood control and 1,811,300 acre-feet for power. There is no allocation for navigation.

Since flood control space is usually empty, especially during a drought, navigation would have to compete with hydropower during a long-term shortage. The two uses are partially complementary because water discharged for power generation is also available for navigation. However, there are often timing conflicts between navigation, which prefers steady constant flow, and hydropower, which creates wide fluctuations in flow. These conflicts would have to be resolved in a shortage.

There are approximately 15,171,000 acre-feet of storage in the Red River Basin, which is 69% of annual average flow and 207% of annual drought flow. Flood control allocations reserve 70% of the storage space. The remaining 30% (4,535,000 acre-feet) is available for multipurpose uses.

9. Planning Structure and Corps Control. The Lake master plans provide the basis for management decisions concerning releases to support the various uses. In order to facilitate continuity in the development, operation, and maintenance of Corps projects and to allow for the reassessing of priorities in light of changing economic, social, and political conditions, a Corps report dated 1 November 1971, provides the authorization for reevaluating projects and updating master plans. Work presently underway includes the preparation of a master plan for the Ouachita and Black Rivers navigation project area and updating the previously prepared plans for the three lakes.

The Ouachita River Basin Comprehensive Survey was authorized by a resolution of the Senate Committee on Public Works adopted on 5 October 1972. The primary purpose of the study is to develop implementable plans for the management and wise use of the river basin's water and related land resources. The following areas of study were established in the authorizing resolution:

(a) Flood protection.

(b) Wise use of the flood plain.

(c) Navigation facilities.

(d) Water supply management.

(e) Wastewater management.

(f) Recreation.

(g) Water quality.

(h) Fish and wildlife.

(i) Measures for enhancement and protection of the environment.

This study is scheduled for completion in 1985 and is expected to be an important input to future basin management and development.

The Red River system is currently under construction, and only a small portion is currently maintained at a nine-foot depth. The project is presently only 10% complete; completion is scheduled for 1989. The operational planning for the system is therefore still in its embryonic stage.

A Red River Waterway Commission has been created, which consists of nine persons appointed by the Governor of Louisiana. The State of Louisiana amended its Constitution to allow this body, which works with the Corps to purchase lands and conduct other activities related to the construction of the Red River project.

The Corps is currently developing manuals for each lock and dam of the project. These will establish constraints for the operators of the locks and dams and determine which operating decisions can be made on site and which will be referred back to the New Oreleans District.

A computer model for the Red River Basin is currently being constructed by the Southwestern Division, with input from the New Orleans and Tulsa Districts. This model will attempt to analyze potential low flow situations by simulating lake discharges, tributary inflows, and water demand for the system in the future.

The Corps is confident that system operatin will be satisfactory for flood control and that navigation on the channel will be maintained at the authorized depth in years of average flow. This confidence does not extend to future low flow situations which may limit navigation by only allowing lower than authorized depths. The computer model under development at the Southwest Division is expected to provide information leading to a judgment of whether or not navigation activity will be impeded in low flow years.

10. Relative Influence and Impacts of Non-Navigation Users. Recreational development has been extensive around reservoirs and along the Ouachita system. The Corps

has recently completed a master plan for recreational development, and this activity is expected to increase significantly as the plan is implemented.

Recreation areas are planned for each lock and dam area in the Red River system and the Corps plans to spend $30 million (1979 dollars) on all recreational development. Private recreation development is not expected to be significant. Many of the upstream reservoirs have substantial existing recreation development.

Recreation and other interests have extensive input to the Corps through an established public involvement program. On an annual basis, the Vicksburg District holds public meetings on a barge attached to a Corps boat. This boat stops at six to eight cities over a four day period, and public input concerning waterway operations is solicited. Most inputs are requests for more extensive access for recreational activity.

Navigation interests maintain contact with the Corps on an informal basis, communicating requests to district headquarters or project operators.

While insufficient water supply for navigation and other uses is not a major concern at the present time, it is recognized that increased water consumption and lockage demands may cause conflicts in the future. This is one of the topics that will be addressed by the Ouachita River Basin Comprehensive Survey previously mentioned. In the Second National Water Assessment, the Water Resources Council recommended the financing of raising the dam at the Columbia Lock and Dam by 1.5 feet to ensure a nine foot deep navigation channel under projected withdrawal conditions by the end of the century.

If conflicts are to arise on the Red River, they will be due to the low flow years currently under evaluation in the Southwestern Division. It is conceivable that changing reservoir management practices to assist navigation activity by augmenting low flows would be detrimental to recreation and sometimes to hydropower interests. However, the possible courses of acton will not be well formed until low flow problems, if any, are better identified.

11. Conclusions. Increases in consumptive water usage by 2000 will create water shortages in the Ouachita River Basin by 2000 during a drought. The largest water

use is irrigation which is highly concentrated in the late summer and early fall when streamflows are lowest. This shortage of water will amplify the conflicts between hydropower and navigation over the available storage.

The Ouachita River Basin Comprehensive Survey will be a key input to determination of future Corps actions. Since the relative importance of future problems on the system is not well defined at present, findings of the survey will be the key for future Corps actions.

Water availability for navigation is not expected to be a problem on the Red River. However, it is likely that the Red River will be affected by the same problems of irrigation and groundwater mining, which will be prominent in the Arkansas Basin. The headqaters of the Red are located in the High Plains area, and the Red River Basin is a possible source for water transfers.

If flow problems for navigation are found to be significant in the Red River, the Corps could consider a number of actions.

Water demand management may be necessary to increase water consumption efficiency through economic incentives or other means. The Corps would be an information and advisory source for this option.

Reservoir management is an important Corps option, as storage could be switched from one use to another. The extensive storage in the reservoirs leading to the Red River make this option viable.

Construction of new reservoirs is possible, as sites have been identified. However, current political resistance to this option is strong and the political climate would have to change.

Interbasin transfers have not been considered since no problem has been identified. It is unlikely that this could be an economically feasible alternative.

12. Critical Factors and Data Gaps. Very little can be concluded for these two systems since they do not have a comprehensive development plan in the Ouachita case and even the final design is not complete for the Red River Project. Potential use of Red River water in Oklahoma is a possible unknown factor, but the ongoing study of water

quality constraints on other users should contribute to the understanding of the potential problems for navigation.

(c) Region 6:
Missouri River

This region (see Figure III-I) figures prominently in any discussion if future water availability problems due to its extent in the Great Plains area and the major new projects proposed there. These factors and their effect on navigation are discussed below:

1. Present Water Supply. Existing monthly streamflows on Segment 10 as measured at Hermann, Missouri are shown in Table A-15 of Appendix A. Both average flows and drought flows with a 95% exceedance probability are included in the table.

These flows reflect 1975 water consumption and level of development. Thus, in a very general manner, the effects of releases from the six main stem reservoirs are included. However, these flows do not show the impact on navigation that can result from specific releases from these reservoirs.

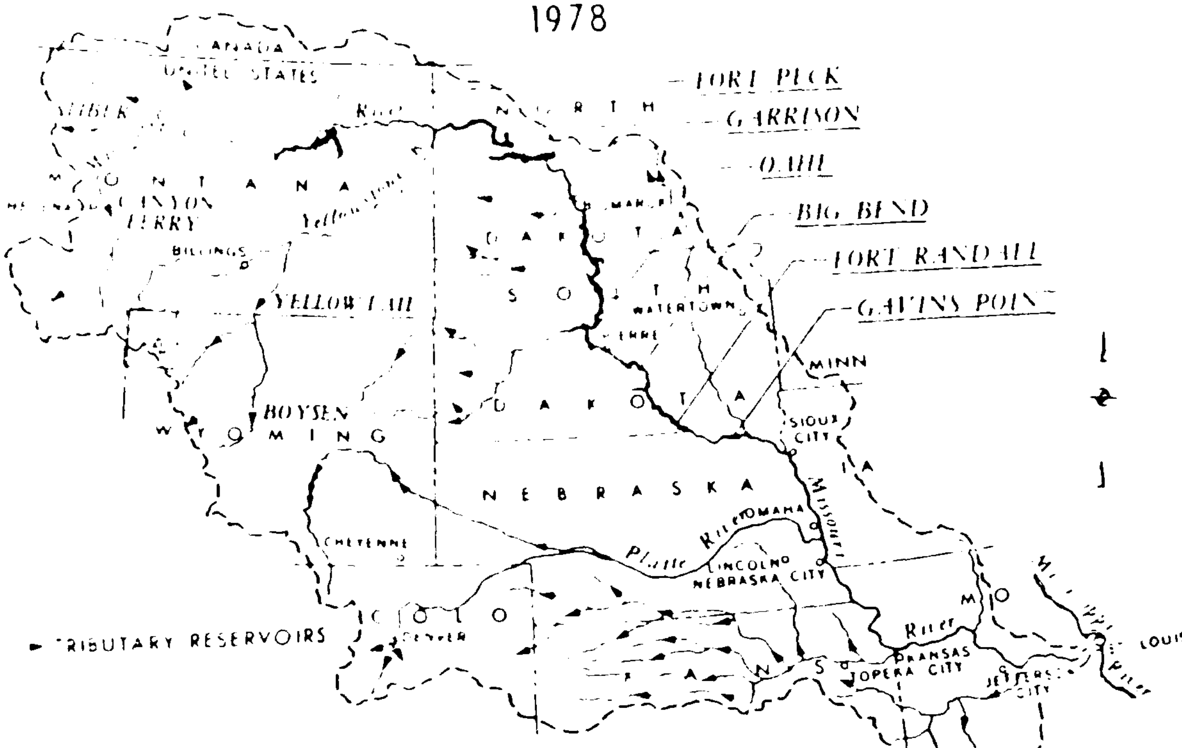
2. Present and Future Water Demand. The existing and projected water demand in the Missouri Basin is shown in Table A-18 of Appendix A. Monthly demand for 1975 and 2000 is disaggregated by type of use, and total use is shown for five year increments in between. Water demand in the upper part of the basis (the water-shed of the main stem reservoirs) is 29% of the total use in 1975 and 39% of total use in 2000.

The most significant category of water consumption affecting Segment 10 is irrigation. In the year 2000, irrigation is projected to be responsible for 89% of all water consumption in the Missouri River Basin in an average year and 90% of all consumption in a dry year. This is slightly lower than the respective 1975 figures of 92% and 93%. The next largest year 2000 projected category of water consumption is livestock, with only a three percent share, followed by power plant cooling, domestic and commercial, "other", minerals, and synthetic fuels.

Irrigation systems in the Missouri River Basin vary substantially by age and type. The two most widely

Figure III-I

1978



MISSOURI RIVER BASIN

used systems are flood and sprinkler types, although combinations anid modification of other types are also employed.

The key element causing water consumption within an irrigation systemis the quantity of water evaporated by the process. There is also some water consumed by growing crops, but this amount is a substantially smaller component. Unfortunately, there have been no comprehensive studies to assess evaporation for the various systems of irrigation. While it is is clear that switching from flood to sprinkler irrigation wil cut withdrawals, it is not clear that the change will reduce consumption. Consumption, defined as the water extracted from a source less the return flows, is what will impact downstream flows.

Switchovers from an existing irrigation system to another, or the planning of totally new systems for newly irrigated land, provides primary consideration to energy costs. As energy prices have jumped, the cost of getting water from source to corps has risen accordingly and new designs seek to minimize energy consumption. Water consumption is not a consideration, although water withdrawals may be important if there is a strict allocation.

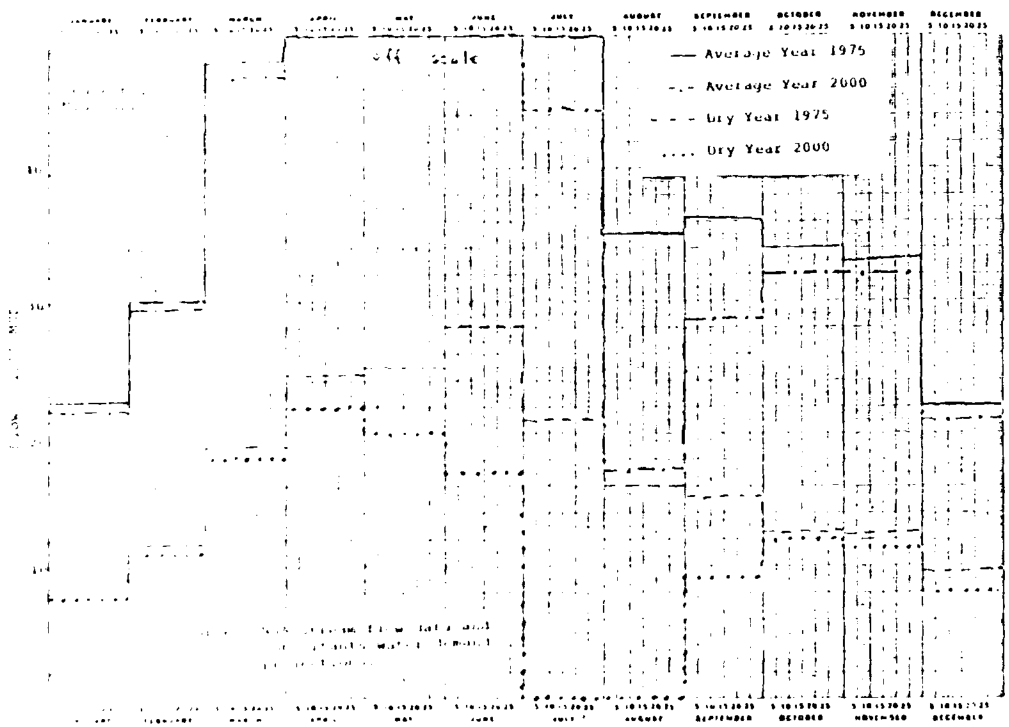
States in the Missouri River Basin allocated water rights, and in the past these rights were granted on a first-come first-served basis. In Wyoming, industrial or utility entities sometimes purchase a farm or ranch and request to transfer water to an industrial facility or power plant. These transfers are assessed considering water withdrawn from a source, and not the water consumed.

It is evident that technological research for irrigation systems is oriented towards improving efficiency in the areas of energy consumption and water withdrawals, and improvements in water consumption efficiency are not a goal. Unless economic incentives are attached to water consumption research in the near future, water consumption efficiency cannot be expected to improve significantly by year 2000.

3. Future Water Availability. Future streamflow in the Missouri River is shown in Figure III-J for average and drought conditions. The graph was constructed by subtracting the increase in monthly consumption between 1975 and 2000, from the existing 1975 streamflow. There are

Figure III-J

Missouri River, Stream Flow Data



two months under a drought situation when the increase in consumption is greater than the existing flow. In the Missouri system this problem would not necessarily reduce streamflows to zero because of the large volume of storage available in the mainstream reservoirs. The effects of reservoir operation on streamflow and navigation are considered in part six below.

Major additional depletions are forecast for the Missouri Basin after 2000 by the Water and Power Resources Service. These will create further water availability problems. Another significant factor is that part of this upstream water demand is in fact met by the drawdown of groundwater in the high plains aquifers. In much of the Missouri basins this drawdown does not significantly affect surface water flow. The most pertinent information for surface water flow is therefore depletion from upstream tributaries and reservoirs. This data was forecast as shown in Table III-7. These depletions, if they occur, will amount to 36% of future additional basin consumptions by the year 2000.

4. Depth Relationships to Navigation. According to shipping interests, on the Missouri the minimum depth that allows commercial navigation is seven and one-half feet as measured at Kansas City. The usual loading depth is eight feet for barges. The relation between depth and discharge according to the Corps varies due to shifting channel bottom morphology as much as one to 1.5 feet between the spring and fall. The average relationship is estimated below for the Kansas City section.

Depth (feet)	Discharge (cfs.)	Discharge (MGD)
9.0	45,000	29,000
8.5	40,000	26,000
8.0	38,000	24,500
7.5	35,000	22,500
7.0	33,000	21,000
6.5	30,000	19,000

Navigation is little affected on the Missouri River during flood flows. The large volume of upstream reservoir storage, and the regulation effect produced by the most downstream Gavins Point project, both allow a high degree of control over downstream flows. High stages have occasionally slowed traffic because of concern that

Table III-7

Additional Annual Depletions for the Missouri River and its Tributaries Over 1975 Levels

Location	1980 (MGD)	1980 (MAF)	1985 (MGD)	1985 (MAF)	1990 (MGD)	1990 (MAF)	1995 (MGD)	1995 (MAF)	2000 (MGD)	2000 (MAF)	2020 (MGD)	2020 (MAF)
Above F. Peck	49	0.1	97	0.1	146	0.2	200	0.2	260	0.3	852	1.0
Ft. Peak-Garrison	90	0.1	242	0.3	448	0.5	684	0.8	992	1.1	1481	1.7
Garrison-Oake	59	0.1	122	0.1	241	0.3	522	0.6	687	0.8	807	0.9
Oake-Big Bend	0	0	6	0.0	6	0.0	6	0.0	6	0.0	17	0.0
Big Bend-Ft. Randall	0	0	0	0	0	0	0	0	2	0.0	29	0.0
Ft. Randall-Garrison Pt.	0	0	0	0	0	0	9	0.0	52	0.1	138	0.2
Total Additional Depletions	198	0.3	467	0.5	841	1.0	1421	1.6	1999	2.3	3324	3.8

MGD = Millions of Gallons per Day.
MAF = Million Acre Feet.

SOURCE: Water and Power Resources Service, unpublished papers. Converted to MGD by the Consultant.

wavewash would erode saturated banks. Flow velocities have not been reported as being high enough to significantly affect navigation.

5. Historic Problems for Navigation and Corps Actions. Commercial navigation on the Missouri River operates over a free flowing stretch from Sioux City, Iowa, to the mouth. It is dependent upon low flow supplementation from the mainstream reservoir system, with occasional assistance from certain tributary reservoirs. Navigation is limited to the ice-free season, which normally lasts eight months, from about the end of March to December. Efforts are made whenever flow and ice conditions permit to extend the season; however, it is also necessary to shorten the season during infrequent critical low flow periods. This occasional shortening is considered preferable to reducing releases below what are considered minimum satisfactory service levels during the navigation season.

In general, navigation operations in the Missouri are considered to proceed smoothly along established guidelines, with special requests for other uses honored whenever possible. When special requests do arise, they usually concern minor flow augmentation for fish and wildlife, and accommodation has not been difficult in the past.

Determination of the length of the navigation season is made on the basis of the level of reservoir storage in the upstream reservoirs. There are no plans to modify this decision method in the near future.

6. Future Navigation Flow Problems. Future water availability for navigation depends primarily on the amount of water stored in the mainstream reservoirs. As consumptive water use grows there is less water in the reservoir which can be used to support navigation. The relationship between navigation and storage was analyzed and the results of that analysis are presented here as Table III-8.

Consumptive water use in the upper Missouri Basin presently averages 4558 MGD (4.99 million acre-feet annually). By 2000 this is forecast to increase to 8057 MGD, (8.82 million acre-feet annually), an increase of 3499 MGD (3.83 million acre-feet annually).

At the present time there is an 88% probability that there will be enough water stored in the mainstream

Table III-8

Percent of Time Navigation Season Equated or Exceeded Under Various Assumed Depletions

Season Length (months)	Existing (1970) Condition	Increase in Depletions from 1970 to 1980 (million acre ft)				Increase in Depletions from 1970 to 2000 (million acre ft)			
		1.0	1.1	1.2	1.4	2.6	3.1	3.7	5.0
8	88%	83%	83%	83%	77%	72%	69%	68%	64%
7.75		86%	86%	84%	82%		70%		
7.5				86%	83%		71%		65%
7.25	89%	89%	84%		84%	73%	72%		68%
7			86%	88%		74%	73%	71%	
6.75					87%	77%	76%		
6.5						80%		72%	
6.25	92%					84%	81%		69%
6	95%						82%		
5.75	100%	90%	89%	89%		85%	83%	79%	72%
5.5		91%	90%	90%	88%	86%		80%	76%
5.25	3%					87%	86%	81%	83%
5		92%	94%	94%	89%				84%
4.75		97%	99%	97%	99%			82%	85%
4.5				100%				85%	88%
4.25						88%			
4						97%	95%	94%	93%
0						98%	98%	97%	100%

reservoirs for a full navigation season. There is zero probability that there will be no navigation. By 2000 with an increase in depletions of approximately 3.7 million acre-feet per year there is only a 64% probability of having sufficient water for a full season. There will be a seven percent probability of no navigation season.

Thus, as water consumption grows the impact will not be felt in reduced depths but in reduced reliability of the navigation season. Shortened seasons will occur more frequently and the possibility of no navigation for a year will increase.

7. Reservoir System. The Missouri River system has established priorities as directed by Congress. The following priorities are presently observed.

(a) First, flood control will be provided for by observation of the requirement that a block of space in each reservoir will be vacant at the beginning of each year's flood season, with evacuation scheduled in such a manner that flood conditions will not be significantly aggravated if possible. This space is available for annual regulation for flood control and all multiple purpose uses, but should be vacant at the beginning of each year's flood season.

(b) Second, all irrigation and other upstream water uses for beneficial consumptive purposes during each year will be allowed. This allowance also covers the effects of upstream tributary reservoir operations, as anticipated from operating plans or from direct contact with the operating agencies of these reservoirs.

(c) Third, downstream municipal and industrial water supply and water quality requirements will be provided.

(d) Fourth, the remaining water supply available will be regulated in such a manner

that the outflow from the reservoir system at Gavins Point provides for equitable service to navigation and power.

(e) Fifth, releases from the reservoirs above Gavins Point are scheduled to provide the efficient generation of power to meet the area's needs consistent with other uses, and power market conditions will be provided for.

(f) Sixth, insofar as possible without serious interference with the foregoing functions, the reservoirs will be operated for maximum benefit to recreation, fish and wildlife.

8. Storage Availability. Main stem storage on the Missouri River is summarized in Table III-9.

Table III-9

Main Stem Storage on the Missouri River (1000 acre feet)

Project	Exclusive Flood Control	Annual Flood Control and Multiple Use	Carryover Multiple Use	Inactive	Total
Fort Peck	1,000	2,700	10,900	4,300	18,900
Garrison	1,500	4,300	13,400	5,000	24,200
Oahe	1,100	3,200	13,700	5,500	23,500
Big Bend	60	117	270	1,730	1,907
Fort Randall	1,000	1,300	1,700	1,600	5,600
Gavins Point	6,062	97	195	165	517
TOTAL	4,822	11,714	39,665	18,488	74,624

In addition to the storage shown in the table there are numerous smaller reservoirs on tributaries, especially in the lower basin..

The total storage shown in Table III-9 is 155% of the annual average flow of the Missouri River and 387% of the annual drought flow. The "annual flood control and

multiple use" storage and the "carryover multiple use" storage which can be used for navigation comprise 108% and 270% of annual average and drought flows respectively. Control of a river to this large a degree is very rare and allows great flexibility in the use of the water resource.

9. Planning Structure and Corps Control. The Coordinating Committee on Missouri River Mainstream Reservoir Operations was established to coordinate and consolidate the viewpoints of all the interests concerned so that they may be adequately represented in the preparation of annual operating plans. All operations, of course, must be conducted in accordance with the guidelines of the Congressional Authorization. The Coordinating Committee's role is to ensure that the annual operations provide equitably distributed services to all the functions and interests for which these projects were constructed. The Committee consists of representatives of all the basin states and the following federal agencies: Corps of Engineers, Western Area Power Administration, Public Health, Federal Energy Regulatory Commission, Fish and Wildlife, National Weather Service, Geological Survey, Water and Power Resources Administration, EPA and Department of Agriculture.

The Coordinating Committee meets twice a year. A spring meeting is devoted to the consideration of operational objectives that each member wants considered in firming up plans for subsequent years operation. With this guidance the Corps Reservoir Control Center prepares a tentative operating plan and, in a subsequent fall meeting, presents the plan to the Committee. The Committee recommends any modifications that are desirable and adopts the plan for the coming year.

The Annual Operating Plan provides a broad framework for day-to-day reservoir regulation. Short-term regulation procedures based on hydrologic and meteorological conditions which cannot be forecast sufficiently in advance for long-range planning and which also conform to the developed operating plan, are developed by the Corps Reservoir Control Center. The detailed responsibility for water an power management on the mainstem and the coordination of tributary reservoir regulaton rests with the Reservoir Control Center.

10. Relative Influence and Impacts of Non-Navigation Uses. As previously detailed, the Missouri River system is managed through a clear system of priorities, as set

by Congress. As the water situation gets tighter, it is possible that these priorities could be *modified*. If the navigation season currently, a lower priority item, was shortened significantly beyond present guidelines, shippers would probably not find it advantageous to continue operations.

An important element of possible future water shortages in the Missouri River Basin will be the growth of private and public irrigation activity. President Carter has currently halted plans for large-scale development on the Oahe and Garrison projects, but these could be renewed. Private development will probably be more important than present levels and future economic factors will determine the magnitude of investment committed to irrigation activity.

Shortages may also bring problems in cooperation between the states. North Dakota, South Dakota, Wyoming, Colorado and Montana have no commercial navigation activity on the mainstem of the Missouri, and decision makers there probably assign more importance to water for irrigation vis a vis navigation than states where navigation is present. Conflicts concerning water use arising from varying economic outlooks from the states' perspectives will most likely have to be resolved through federal decision.

The communication between the Corps and groups of waterway users if fairly good at the present time. Irrigation interests are represented in the Coordinating Committee by the state engineers and the Water and Power Resources Administration. Navigation interests are constantly advising the Corps of conditions warranting attention within the system. Recreation interests also are in contact on an informal basis.

11. Conclusions. Because of the congressionally authorized priority system, as consumption grows navigation will suffer. The past procedure and the expected procedure in the future will be to reduce the navigation season length as opposed to reducing depth as less water is available. The result will be decreased service and reliability to commercial navigation.

As the water availability in the Missouri River Basin becomes more constrained, the decisions to be made

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will involve determining which types of water users maintain access, and which types will be forced to restrict growth. Political accommodations will have to be made among the various interests. However, Corps representatives believe that this situation is not feasible until the end of this century, barring a long-term drought.

Water demand management, through requirements of improving irrigation efficiency, limiting access, or imposing user charges, could have a significant impact downstream, but this is not an option where the Corps has control. There also are strong institutional barriers to implementation of these types of programs.

Distances to sources and the vast amounts of water necessary do not make interbasin transfers economically feasible for the Missouri River Basin.

Reservoir operation can be used by the Corps to respond to changing user needs, depending upon available water storage. It can be expected that operation for hydropower will be emphasized in the future due to continually rising energy prices. The extensiveness of the storage system in the Missouri Basin allows great operational flexibility, but the priorities set by Congress severely constrain what can be accomplished with that flexibility. There is some room for compromise in the existing planning structure. However, as long as consumption is given first priority the Corps will be restricted to managing what water is left over.

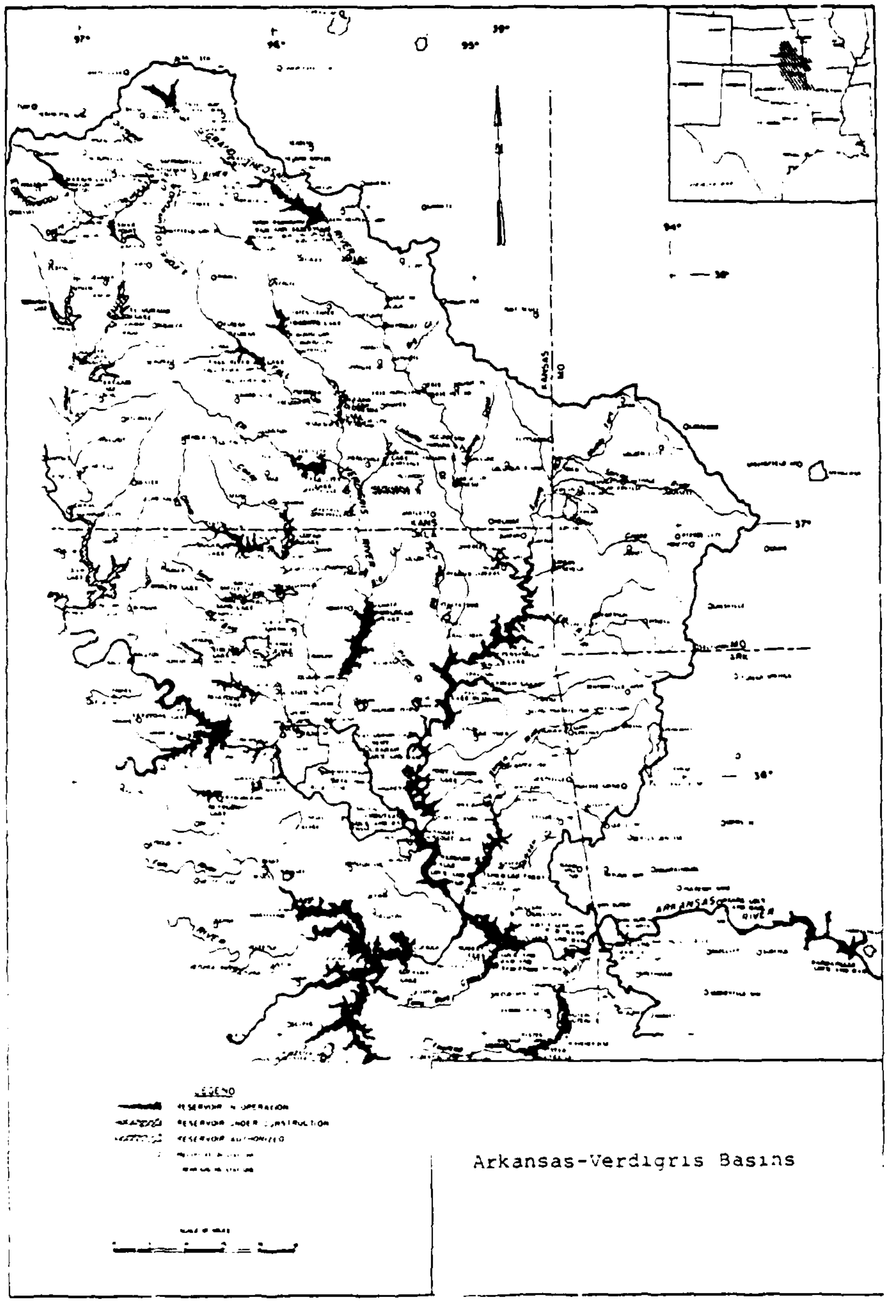
12. Critical Factors and Data Gaps. More is known about the impacts upon navigation of multiple use competition for water resources in the Missouri Basin than any other basin. The only unknown is when a given level of depletion will occur. The effects on navigation of the depletion are well documented. The most important factor in these depletions is irrigation use of water. Future growth of irrigation in the upper Missouri Basin will determine the level of service available to navigation.

(d) Region 9 -
Arkansas River

This river basin (See Figure III-K) has similar long-range water problems related to irrigation in the Great Plains, but they virtually no impact on navigation due to several special circumstances, which are examined below.

Figure III-K

Arkansas-Verdigris Basins



1. Present Water Supply. Water available in the Arkansas Basin under 1975 conditions is shown in Appendix A, Table A-15. An average hydrologic year and a drought (95% probability of exceedance) year are included in the table. Annual drought flows are approximately 29% of average flows (27000 MGD). The variation between the maximum month and the minimum month is 332% for an average year and 727% for a drought year.

2. Present and Future Water Demand. The most significant category of water consumption affecting Segment 24 is irrigation. In the year 2000, irrigation is projected to be responsible for 82% of all water consumption in the Arkansas Basin in an average year and 85% of all consumption in a dry year. This is lower than the respective 1975 historical figures of 88% and 89%, as irrigation use in the basin will decline slightly as other uses grow. The next largest uses for year 2000 average conditions are domestic and commercial and industrial, each with 4% share, followed by livestock, power plant cooling, minerals, and synthetic fuel development (See Appendix A, Table A-19 for detail).

To discuss the Arkansas system, it is important to note the significance of flows in different parts of the basin and their relation to navigation. Water in the western portion of the basin are common, and total flow along these tributaries is small compared with water flow in the eastern portion of the basin. Eastern basin tributaries, particularly the Verdigris River basin, are more important to navigation. (See map in Figure III-K).

Three technology factors will dictate future water demand in the Arkansas Basin and its effect on navigation. These are in the fields of groundwater mining, salt constraints on water use, and water transportation. Each of these is discussed below.

A prime reason why this segment was identified as having the potential for water conflicts was the fact that groundwater mining is not a suitable long-term water supply and it was assumed, as a worst case situation, that all water demand would have to be satisfied through renewable sources by 2000. If this assumption were to be accurate there would be great additional pressure on the limited water resources of this basin since 73% of present irrigation water and 63% of all water consumption in the basin comes from groundwater overdrafting.

The major aquifer in the western part of the basin is the Ogallala Formation, which underlies most of the High Plains area of the mid-continental United States. Although it is not the only aquifer impacted by overdrafting, the Ogallala is one of the most extensive aquifers in the mid-continental area and also has the most severe overdrafting problems. This is because rainfall in the area averages only 10 to 20 inches per year but the combination of a seemingly boundless supply of good quality groundwater, low cost energy to pump it, deep fertile soils, level terrain and favorable climate has resulted in the rapid expansion of investment in irrigated agriculture, with a tremendous increase in agricultural production and associated agribusiness since the 1930s.

In the last 30 years, land under irrigation in the High Plains has expanded at an annual average rate of about 7.5%. Feed grain production in the area has risen even faster and has triggered another development in the regional economy - the feed lot industry. Prior to 1950, the number of cattle on feed was insignificant. By 1973, the area was marketing ten million feed cattle annually, forty percent of the nation's feed beef market. With the expansion of land under irrigation came an associated increase in agribusines. Supporting economic sectors supplying pumps, tubular goods, sprinklers, fertilizers, pesticides, processing plants and farm equipment are not established in the region. This represents a substantial economic interest in preserving irrigation in the western part of the Arkansas basin.

Predictions vary as to the time left before the water resources of the Ogallala will be depleted beyond the point of being economically recoverable. The thickness of the formation varies from a feather edge to over 1000 feet. It has a marked lack of homgeneity in the physical characteristics that determine how much water can be stored or recovered in a given area. Irrigation pumpage has proceeded at differing rates in different areas. Because of these variances, the rate of depletion and the time of ultimate loss of the irrigation potential range widely over the aquifer. In some areas where the geologic formation is thin, land has already gone out of irrigation. Under a continuation of present practices, many other areas are predicted to go out of irrigation over the next two to three decades, unless other sources are tapped.

Although this basin-wide water shortage will get more acute as the groundwater levels are reduced through groundwater mining, the main impact of this problem is felt in the most western parts of the basin. Since these High Plains experience little rainfall, they account for only a small portion of the surface water in the basin. Therefore, use of surface water in this part of the basin has little effect on water availability for navigation which is all carried out in the eastern part of the basin, downstream from Tulsa.

There could be an impact, of course, if water were transferred to the western part of the basin from the eastern part. Due to increasing awareness of future water availability problems, it appears unlikely that water transfers between states will occur in the basin. However, it is still possible that these transfers could occur within a state and this possibility has been examined in detail for Oklahoma, the centrally located state in the basin. This information is documented in the Oklahoma Comprehensive Water Plan.[1]

This plan proposes two major conveyance systems, which have been further examined for economic feasibility by the United States Army Corps of Engineers.[2] These further studies have not been able to identify any economically feasible conveyance system. Consequently, this analysis assumes that significant future transfers over long distances (more than 50 miles) within the basin will not take place.

The potential impact of water availability for navigation then becomes a question of surface water withdrawals within an economical pumping distance of the mainstream river. This area is the focus of an on-going analysis called the Arkansas-Red River Basin Chloride Control Study, which also details water quality problems that could limit consumptive water use in the area.

The area of potential river water use was determined to lie within 40 miles of the river. This area contains 688,000 irrigated acres which, accounts for about 20% of total irrigated acreage in the river basin. Both present and potential water use was studied in detail for this area as far upstream as the eastern edge of the Oklahoma Panhandle. A summary of present water use in this area is shown in Table III-10. From this table it can be seen that 80% of present water consumption near the

Table III-10

1977 Water Use Within Economic Transportation Range of the Arkansas River (MGD)

Reach	Municipal		Industrial		Cooling		Irrigation		Total	
	Ground	Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground	Surface
1	31	65	47	10	1	0	614	218	693	293
2	*	28	1	3	*	938	3	2	4	971
3	0	9	*	4	0	0	1	2	1	15
4	*	3	0	*	0	79	1	1	1	83
5	*	99	2	13	0	9	1	1	3	122
6	1	7	0	1	0	0	1	*	2	8
7	*	1	0	0	0	0	*	*	0	1
8	13	6	4	1	*	14	2	1	19	22
9	3	9	*	*	0	0	*	*	3	9
10	3	2	1	2	0	0	22	6	26	10
11	7	*	5	0	2	0	83	7	97	7
TOTAL	58	229	60	34	3	1040	728	238	849	1541

NOTE: *less than 0.5.

SOURCE: Working papers for the economic analysis section of the Arkansas-Red River Chloride Study.

Arkansas River occurs in reaches one and two, which contain the Arkansas State portion of the river basin. These uses are dominated by irrigation use in reach one and cooling use in reach two, both of which lie in the eastern part of the basin where water is relatively plentiful. The demand in the western part of the basin within economic transport distance (40 miles) is not significant for total available flow in the Arkansas River.

Economic forecasts for reaches one and two indicate a slow continued growth in irrigation, 90% of which will continue to occur in reach one. Cooling water from the Arkansas is expected to increase very slowly in water as water saving technology counteracts the sharper growth in projected energy demand. The net result is that total water demand in this area is expected to increase only by approximately 10% between 1977 and 2000.

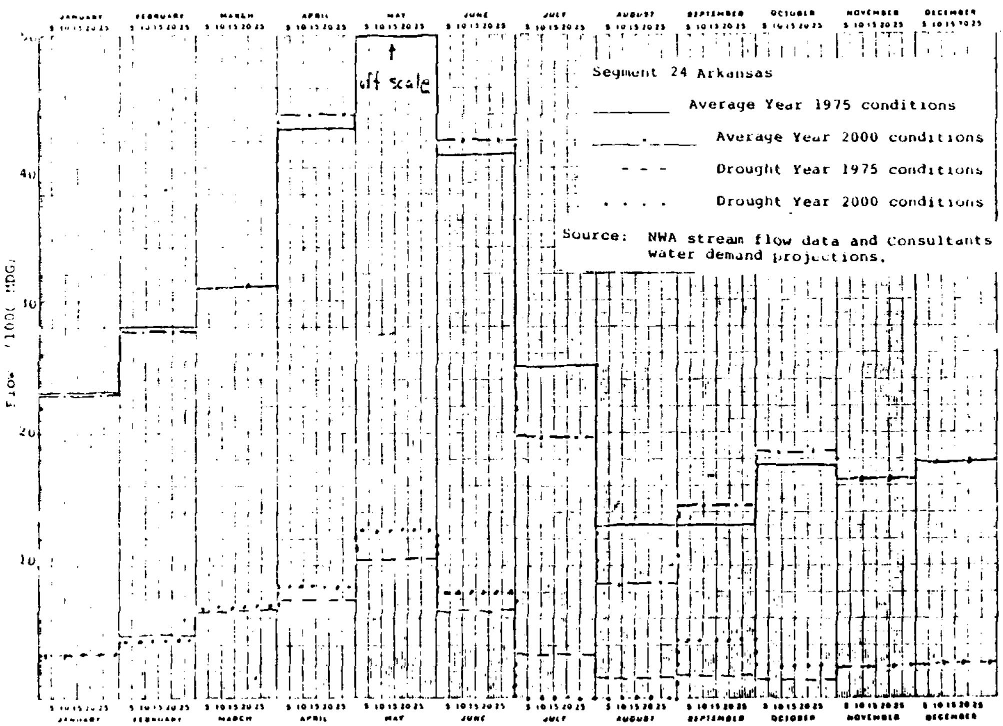
Most of the water supply to meet this demand presently comes from groundwater in the river alluvium, a source which will continue to be available. The river water itself is polluted by high salt content, particularly in the upstream sections, which limits its usefulnesss, especially for agriculture. Recent studies of chloride control on the Arkansas appear to show that it will not be feasible to reduce this salt content by technical means. Although agricultural techniques are being uses to develop more salt-resistant crops, this does not seem to promise a major change by 2000.

3. Future Water Availability. Given this supply and demand forecast in the area near the river that could conceivably draw on river water, it is clear that withdrawals of water from the river and its major tributaries will not increase significantly by the year 2000, and therefore, there will not be any significant effect of future water consumption in the basin on water availability for commercial navigation on the Arkansas River.

The amount of water available in the Arkansas Basin in 2000 is shown in Figure III-L. The figure is a graph of monthly flows for drought and average occurrences for 1975 and 2000 conditions. Both year 2000 stream flows and maximum forecast water consumption increase are shown. Since water location and quality factors restrict the possible use of stream flow, it is probable that even under drought conditions water will be available for navigation.

Figure III-L

Arkansas Basin, Stream Flow Data



In the graph, some months actually show an increase in supply while others show significant decreases. This is a result of increased peaking of water demand for irrigation in the future. It should also be noted that during a drought in the year 2000, water demand exceeds supply in July and August for the basin as a whole, but that the navigable part of the river will have sufficient flow to support navigation, since this source supports only 25% of the demand shown.

4. Depth Relationships to Navigation. The navigation conditions during past flow periods are reported to have been uniformly good on the Arkansas since this is a canalized river. Barges are normally loaded to eight and one-half foot drafts. Towboats are typically seven and one-half foot draft. Triple screw engines are considered important because of the long distances required for servicing (nearest facility is Greenville, Mississippi, which could entail a 500 mile trip).

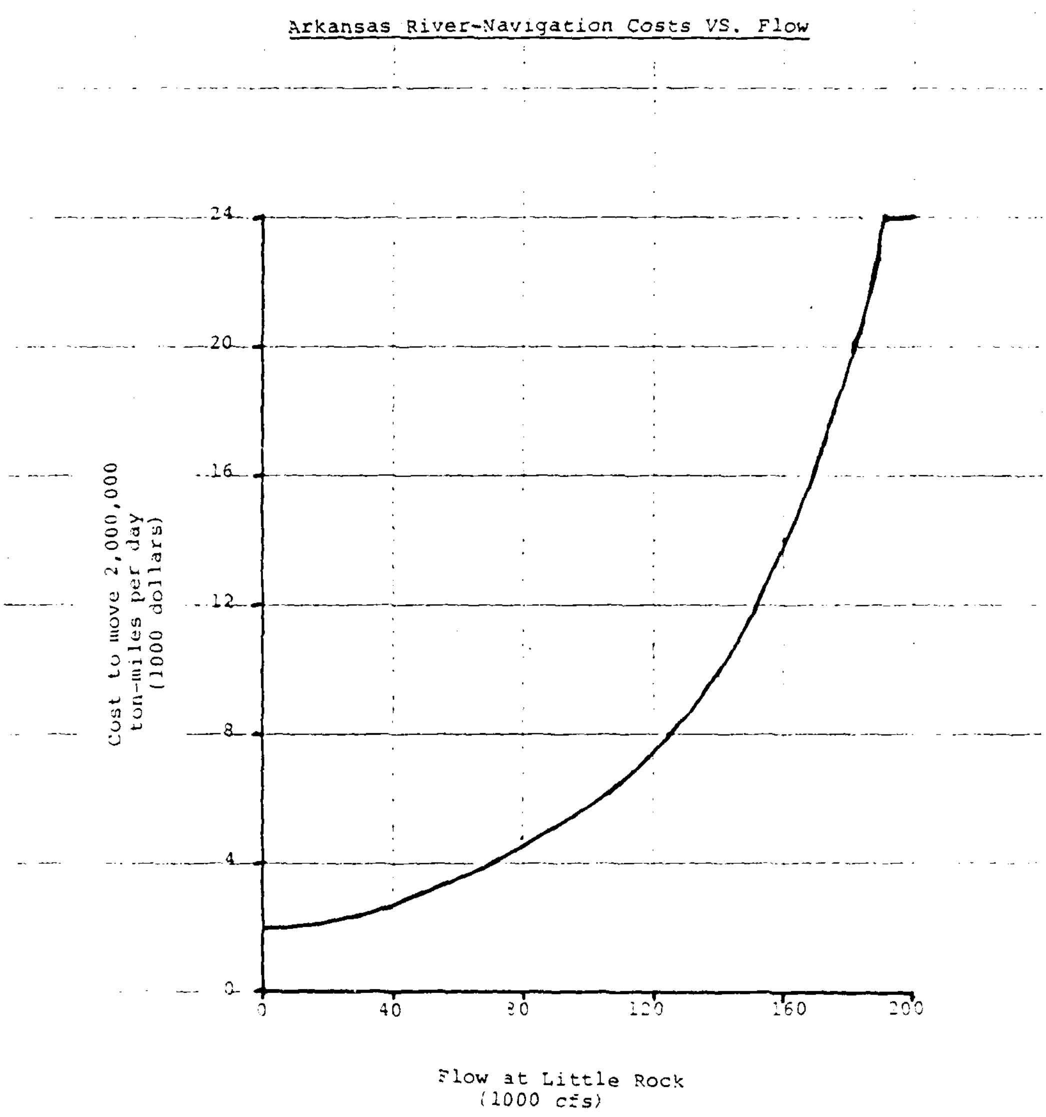
Navigation to the most upstream point on the Arkansas Port Catoosa, is maintained to a depth of nine feet. The only flow requirements are for lockages, evaporation, and seepage; and that flow is currently estimated at 140 cfs (90 MGD) for the Verdigris River, which is the most critical part of the Arkansas system for navigation.

High flows pose a constraint to navigation on the Arkansas River. The Arkansas system was designed to allow traffic until the water level comes within two to three feet of the top of the lock wall. However, high velocities produced from flood events increase navigation costs and high water and high velocities occasionally prohibit navigation entirely. An estimated relationship between navigation costs and flow is shown in Figure III-M.

5. Historic Problems for Navigation and Corps Actions. The Corps has been able to maintain a nine foot depth since 1970, with the exception of ocasional shoaling problems. A larger problem has been high flows constraining navigation, as tows are forced to consume extra fuel and reduce the number of barges because of higher river velocities. Problems of high velocities in 1974 caused monetary losses for industrial interests shipping iron and steel along the Arkansas, and these commodities were switched to another mode.

Figure III-M

Arkansas River-Navigation Costs vs. Flow



In consideration of the widely fluctuating natural flow regimes on the Arkansas River, the Corps has placed a high priority upon increasing the confidence of waterway users through incorporation of a navigation tapering plan of system operation. There is a high incidence of flood flows which produce velocities that considerably raise the costs of operations to shippers. The tapering plan extends the time allocated to moderate flows, which are more conducive to navigation, while other projects' purposes are affected in varying degrees. Flood control is improved in terms of residual damages and slightly penalized in terms of reduced reliability. Hydropower is benefited with increased energy production. There is a negative impact on recreation and the environment because of reservoir pool fluctuations.

6. Future Navigation Flow Problems. Because the McClellan-Kerr Navigation System is almost entirely canalized, water requirements are very small. At the present time, there appears to be enough navigation storage in the system to overcome a drought period. However, (as shown in Figure III-L) there could be periods when total basin demand exceeds supply in drought years. As the technology section stated, the increasing general competition for water in the Arkansas Basin over the next two decades will not significantly affect navigation.

7. Reservoir System. All of the major Corps reservoirs were authorized as multipurpose projects, and specific storage is usually allocated for each authorized purpose. The Corps is allowed a certain discretionary authority to transfer the use of storage from one purpose to another. Multiple use of a single storage zone is acceptable where the adverse impacts on any project purpose is small and the benefits to other authorized purposes are large.

The established goals to be accomplished in system operation are presented below:

(a) Flood Control. The greatest portion of flood benefits in this basin are from damages prevented to crops and rural structures.

(b) Power Production. The eight federal hydreopower plants in the Arkansas Basin are integrated into a system of plants

located throughout the Arkansas and White basins. The power is marketed by the (SWPA). Management for the reservoirs where hydropower plants are located attempts to maximize energy generation, meet design capability, and meet the operation requirement for all project purposes.

(c) Navigation. Arkansas River navigation from Tulsa to the mouth was initiated in December 1970. A navigable depth of nine feet will be maintained whenever practicable.

(d) Water Supply. Water supply storage in federal reservoirs is authorized for allocation to a specific user.

(e) Fish and Wildlife Enhancement. The Fall River, Elk City, Council Grove, John Redmond, Wister, Blue Mountain, and Nimrod lakes are regulated for fish and waterfowl enhancement in addition to the other authorized project purposes. This is accomplished through the use of seasonal pool levels. The plans for conservation pool level fluctuations are aimed at producing greater fish and wildlife harvests and more fishing and hunting benefits.

(f) Water Quality. While no legal requirements for water quality exist for the basin reservoirs, releases are made from some projects to aid in meeting control points. Selective withdrawal and dilution releases are two of the available options to meet this objective. Releases are also made for emergency conditions that may occur. Water quality improvement also occurs as a byproduct of releases made to satisfy other project purposes.

(g) Recreation. Recreation is not an authorized project purpose in most of the reservoirs; however, its importance is

highly recognized. Recreation benefits, though difficult to evaluate, are obviously present when practical. Project operatios may be restrained to stabilize pools or limit pool fluctuations in recreation season. The seven Corps lakes which have recreation as an authorized project purpose are Kaw, Birch, Council Grove, Marion, John Redmon, Optima, and Robert S. Kerr. There are also two Water and Power Resource Administration lakes, Chaney and Meredith, which have recreation as an authorized purpose.

8. Storage Availability. There are approximately 9,900 acre-feet of storage in the Arkansas Basin which is 33% of average annual flow and 117% of annual drought flow. However, of this total, over half of 3,915,000 acre-feet are allocated to flood control, which is normally kept empty. The remaining storage is divided between power (3,541,000 acre-feet) and municipal water supply (444,000 acre-feet). One reservoir, Oologah, has 168,000 acre-feet reserved specifically for navigation.

9. Planning Structure and Corps Control. The Arkansas River Basin Coordinating Committee was organized in 1970 to provide coordination between state and federal agencies in the management of the basin. Represented on the committee are the states of Kansas, Oklahoma, and Arkansas and the federal presence of the Corps, Department of the Interior, Environmental Protection Agency, Federal Power Commission, Soil Conservation Service, and the Southwestern Power Administration.

The approved water control plan for the individual projects in the Arkansas River Basin is contained in the water control manual for each project. The water control plan for the system regulation of the projects in the Arkansas River Basin will be contained in the master water control manual for the basin. Any deviation or revision to these plans is subject to approval of the Southwestern Division, Reservoir Control Center.

The Corps has been developing a model to maximize the benefits of system management in the basin. While the hydrologic and economic conditions will change in the future, the model should be valuable in reacting to and anticipating these changes. However, the use of the model

to accurately simulcate system operation at the present time is questionable.

The McClellan-Kerr Navigation System as a whole has not reached maturity. Individual project guide curves will have to be improved in certain cases, and the construction of several new reservoir projects is underway. The availability of low flows will only change if there is a major water transfer in the basin. This is virtually ruled out because the high chloride content of the Arkansas River, and particularly its tributaries, have made water diversions for water supply and irrigation unacceptable in many cases. Both water transfer and salt removal projects do not appear to be economically feasible.

10. Relative Influence and Impacts of Non-Navigation Users. Hydropower demands are dynamic and can be expected to increase in the future as energy prices rise. While releases for hydropower are generally compatible with navigation, the availability for water under drought conditions could approach a critical stage for both hydropower and navigation if they were placed in a competitive situation (e.g., with hydropower generators on locks and dams.)

The rapid growth of the Tulsa metropolitan area has become potential problem at the end of the century. Oologah Reservoir has storage allocated for both navigation and the Tulsa area water supply. While no conflict presently exists, expansion of withdrawals for Tulsa needs may become a major concern for system management.

Recreation has become a major use of the Arkansas River and can be expected to increase in importance. Recreation users have exerted an increasing amount of pressure in order to regulate reservoir levels more to their benefit, although recreation was not included as a project purpose in many reservoirs. There are measurable damages to facilities within the reservoir area during high and low pools. Project attendance is reduced at reservoirs as well as along the river and its tributaries during extremely high and low flows. Consideration of recreation needs is incorporated in release schedules whenever possible, but recreation is sometimes adversely impacted by the mandatory releases for other purposes.

No formal system of communication exists between the Corps and recreation users, but letters and telephone

calls are received often. The Corps attempts to accommodate requests when possible, but system management for other needs often takes precedence.

11. Conclusions. Water availability conflicts in the western Arkansas Basin will increase as a result of groundwater shortages caused by overdrafting for irrigation. Projects have been proposed to transfer water from the eastern portion of the basin to the west. However, the cost of water transfer and of reducing the salt content of river water appear to eliminate any significant effect or water availability for navigation.

The Corps will have to play both active and advisory roles in the resolution of water shortage problems, but these will only peripherally involve navigation.

12. Critical Factors and Data Gaps. As has been discussed and mentioned many times, the most important consideraton in the Arkansas Basin is the outcome of the groundwater mining studies and alternate supplies. If the economics of water transfer and salt removal should change, this could have a significant effect on navigation. Little is known about these problems at the present time, but results of ongoing studies (the Arkansas-Red River Chloride Study, and the High Plains-Ogallala Aquifer Study, in particular) should be published by the early to middle 1980s. The Corps should remain aware of the implications of these studies for navigation.

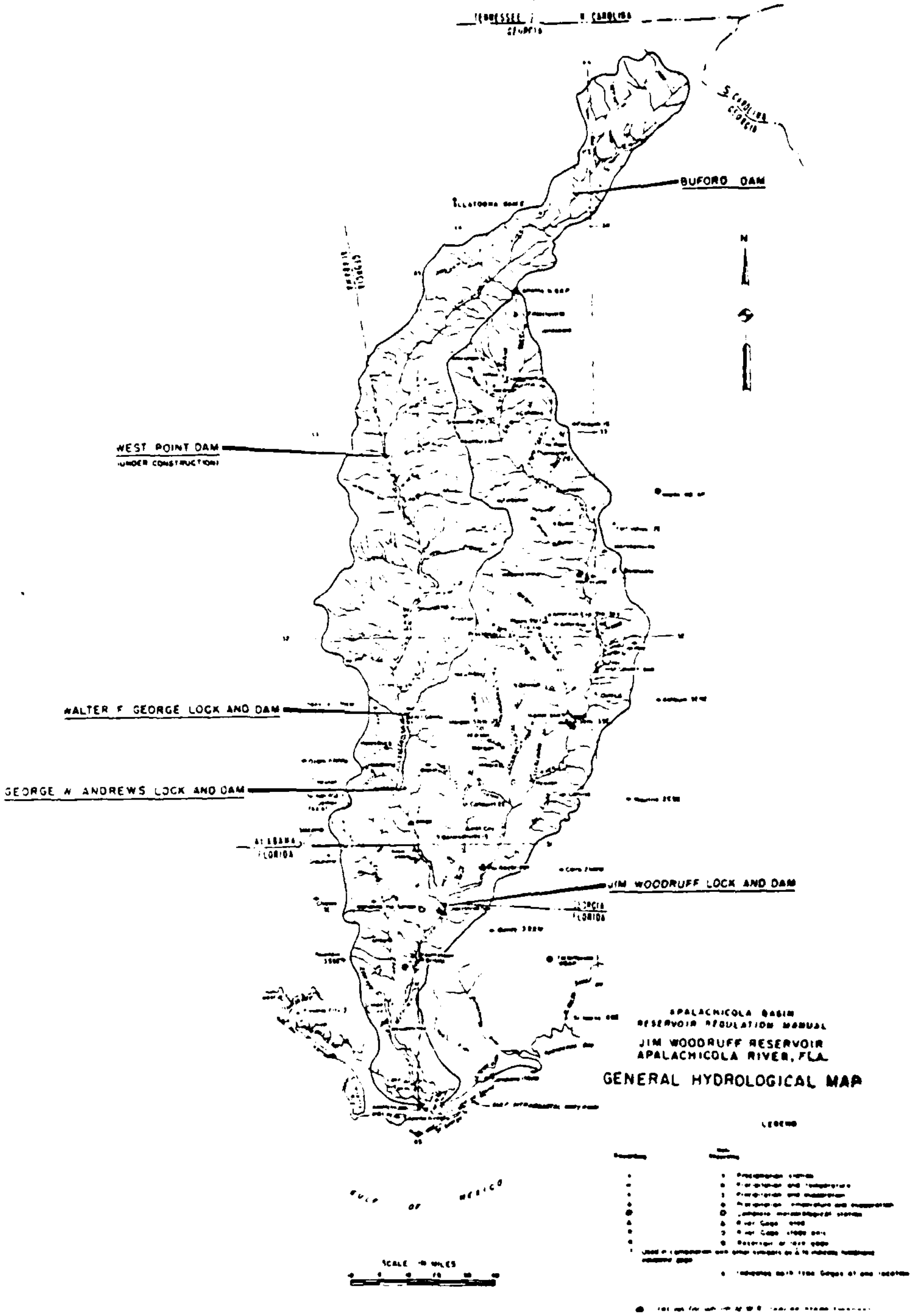
(e) Region 11 - Gulf Coast East

Within this region (see Figure III-N) only the Apalachicola Chattahoochee-Flint (ACF) River System was identified as having a potential low flow problem. In fact, this is a problem that occurs presently during dry years and will worsen slightly in the future. The major factors are described below.

1. Present Water Supply. On the ACF, annual drought year flows are approximately 63% of annual average flows. During a drought year the maximum monthly flows are 386% of the minimum month. The maximum month during an average year is 275% of the minimum month. (See Appendix A, Table A-15 for details).

Figure III-N

Apalachicola-Chattahoochee-Flint Basin



2. Present and Future Demand. The most significant categories of water consumption affecting this waterway segment are irrigation and industrial uses. In the year 2000, irrigation is expected to be responsible for 33% of all water consumption in the ACF Basin in an average year, and 28% in a dry year. In 1975, irrigation accounted for 33% of total consumption in an average year and 43% of total consumption in a dry year. Comparable 1975 figures for industrial uses are 23% and 21%, respectively. (See A-23, Appendix A).

Other categories of projected consumption and year 2000 share are as follows: power plant cooling, 17% in an average year and 16% in a dry year; livestock, minerals, synthetic fuel development and "other," less than seven percent for all categories combined under average or dry conditions.

Groundwater levels in some areas of southwest Georgia appear to be declining. Heavy water use is occuring for irrigation, domestic and industrial purposes. The groundwater aquifers are limestone and sandstone sinks are occurring because of excessive groundwater pumpage.

As irrigation and industrial uses combine to account for the majority of water consumption in the ACF Basin, implementation of processes and systems reducing water consumption in these categories are most important. Irrigation trends are discussed at length in the Missouri River analysis, and the situation is similar in some respects for the ACF Basin. The major difference is that water access has not, until recently, been a major concern in the ACF Basin. Similarities are that consumption and downstream effects have never been seriously researched and incentives to promote water conservation do not presently exist. (See map in Figure III-N).

Industrial uses are discussed in the Alabama-Coosa analysis, and a similar situation exists in the ACF Basin. Water consumption for this use may be slightly lowered due to an energy-saving emphasis, but reductions will be limited.

3. Future Water Availability. The effects of future water consumption upon stream flow are shown in Figure III-N. In this graphic the increase in water consumption from 1975 to 2000 for each month is subtracted

from the existing stream flow for that month. Under average hydrologic conditions the annual consumption increase is 1.5% of annual streamflow, and the worst month is 3.6% of the monthly flow. Under a drought the annual consumption increase is 2% of streamflow and the worst month increase is 7% of monthly flow. This will not have much impact on future water availability.

4. Depth Relationship to Navigation. According to a representative of the local towing industry, the minimum acceptable depth for commercial navigation is seven and one-half feet. This depth represents both towboat minimum draft and economic factors. The conditions on the ACF are similar to the Alabama River in that navigation normally proceeds with frequent "touchings of bottom."

High flows occasionally hinder navigation for short periods of time. The velocities produced during high flows have caused navigation problems for tow operators around bridges and locks. However, because of the infrequency of occurrence and of these problems there was no detailed information available from the Corps.

The stage-discharge relation at Blountstown, the two industry reference point, is as follows:

Depth (feet)	Discharge (cfs)	(MGD)
10	15,000	9,500
9	13,000	8,500
8	11,000	7,000
7	9,600	6,000
6	7,800	5,000

5. Historical Problems for Navigation and Corps Actions. Problems of low flow and reduced depth are relatively common on the ACF navigation system. Although normally a nine foot project, it is often operated with a depth of eight feet during the fall. These problems are mitigated somewhat by releases from Buford Dam. However, the releases which can be made from Buford to aid navigation are constrained by power and recreation demands. Of the two uses only power is contained in the original project authorization.

During low flow periods, flow augmentation in the Apalachicola River is provided by the releases from Buford

Dam. If at all possible, this augmentation is supplied by the scheduled power releases. When more water is needed, consideration must be given to the tradeoffs betwen power, navigation and other water uses. As energy prices rise, power will be given greater preference.

Experience has shown that the time of travel of releases from Buford to Jim Woodruff is approximately six days during low flow periods. This delay makes it even more difficult to plan operations at Buford. However, Jim Woodruff has an allowable drawdown of one foot for pondage, which amounts to 36,000 acre-feet of useable storage. If necessary, water can be borrowed from this storage to supplement natural flows below Jim Woodruff prior to the arrival of water from Buford. This affords some leeway in planning the releases from Buford and permits them to be integrated into the regular power commitments.

In the fall of 1978, the ACF basin experienced below normal rainfall, causing predictions that channel depth below Woodruff Dam would be 6.5 to 7.0 feet unless releases were made from Buford Dam. The authorized depth of the ACF is nine feet but the channel is often operated at an eight foot depth during fall low flow periods. Forecast deficits of stream flow determined the critical period to be of seven weeks duration.

To help facilitate the decision regarding Buford releases in 1978, Corps economists were requested to determine the costs to navigation, hydropower, and recreation if channel depths were reduced from eight feet to seven feet. It should be noted that although recreation is not an authorized purpose at Buford it is so considered as a result of an administrative decision by the Division Engineer.

After weighing the relative merits of costs to navigation, hydropower, and recreation interests, it was decided that navigation should be maintained although at a reduced level of service. In effect the short-term costs to navigation from reduced flows were found to be higher than to hydropower and recreation. The implications of a long-term reduced flow under drought conditions suggested that hydropower and recreation would be given equal consideration with navigation and that the decision would be determined largely by economic considerations.

6. Future Navigation Flow Problems. The impact on navigation of low flows and increasing consumption is shown in Figure III-P. This figure is the same as Figure III-O with the addition of horizontal lines at 8,500, 7,000, and 6,000 MGD, which correspond to navigation depths of nine, eight and seven feet, respectively. As shown in the graph, during a drought year there are already five months with channel depths less than nine consumption by 2000 will cause a total of seven months at less than nine feet and one marginal. Increases in water consumption by 2000 will cause a total of seven months at less than nine feet and one marginal month, in a drought. During average year conditions there should not be any conflicts due to low flow.

7. Reservoir System. Storage of water occurs in three projects Buford Dam (Lake Sidney Lanier), West Point, and Walter F. George. The following uses ae important to operations:

(a) Flood Control. Buford and West Point are authorized to maintain storage for flood control. Storage for this purpose is set by maintaining target pool elevations for specific times of the year.

(b) Power Production. Hydropower output is authorized and is part of a Southeastern regional system. Generation is primarily for peaking purposes.

(c) Navigation. Navigation storage is authorized at Buford. At that project, navigation is allowed one foot in depth in the reservoir for flow augmentation.

(d) Water Supply. This is authorized from multipurpose storage. At West Point, 675 cfs must be released at all times for this purpose. Of particular importance is the supply from Buford to Atlanta, which will be discussed later in this segement discussion.

(e) Water Quality. Legal requirements in the project authorization for Buford provide for releases up to 600 cfs when

Figure III-O

Apalachicola, Stream Flow Data

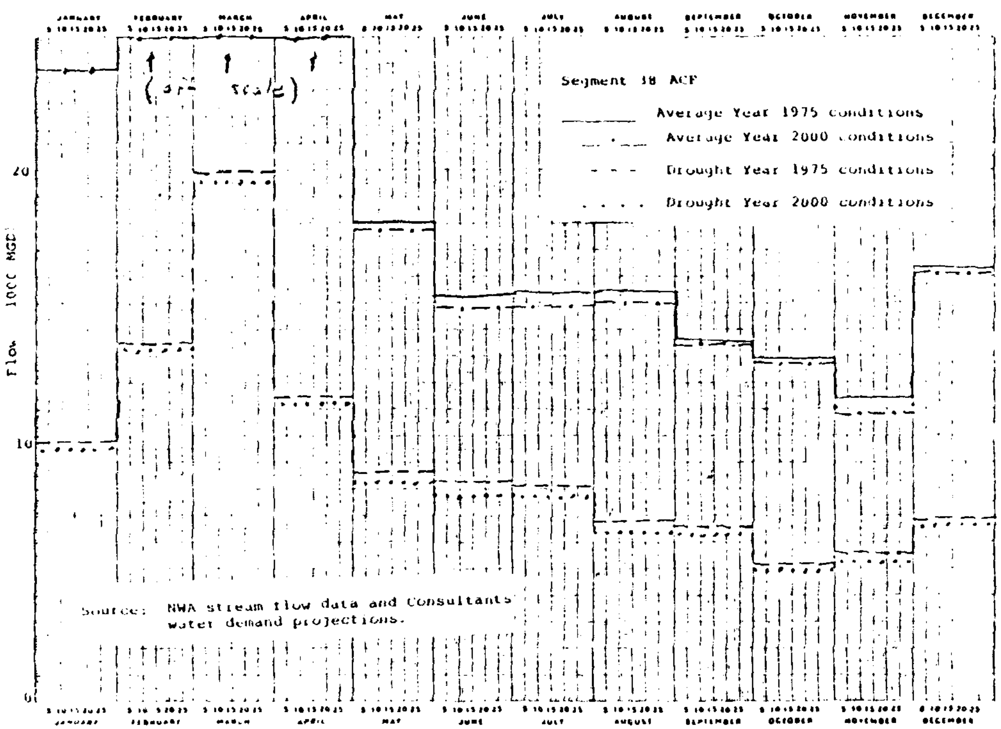
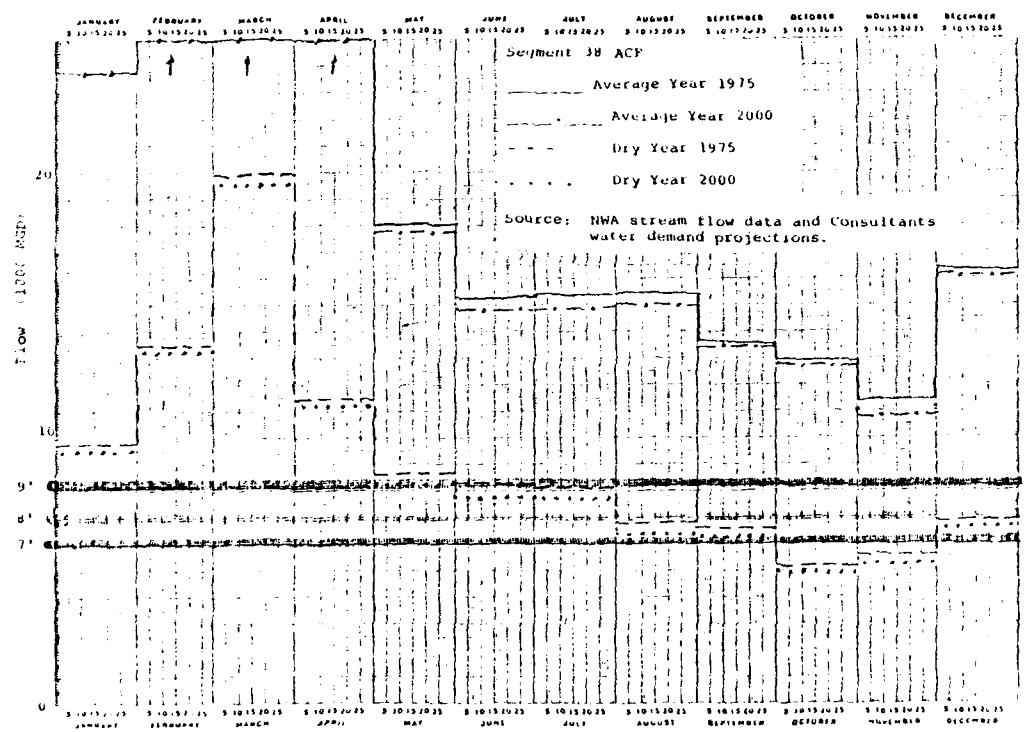


Figure III-P

Apalachicola, Low Flow and Depth Relationship



necessary to maintain 650 cfs at Vinige Gage for low flow augmentation.

(f) Recreation. This is not an authorized purpose but development has been extensive, especially around Lake Sidney Lanier. The importance of this purpose is recognized in management decisions.

(g) Fish and Wildlife Enhancement. This is not legally required, but where accommodation can be made without significant problems for ther users, releases are allowed.

8. Storage Availability. The maximum amount of storage available in the ACF Basin is 1,150,000 acre-feet which is 5.2% of the annual average flow and 8.3% of the annual drought flow. However, most of this storage space is utilized for flood control and is usually kept empty. Normal winter storage is only 205,000 acre-feet, which is less than one percent of average annual flow and 1.4% of drought flow.

9. Planning Structure and Corps Control. The states the ACF Basin (Alabama, Georgia and Florida) have only recently begun to cooperate to study water problems in the area. The Corps has no comprehensive plan for basin management, but the development of such a plan has been proposed and is expected to be authorized and pursued in the near future.

The Corps approaches problems within the ACF system on a case-by-case basis, and attempts to minimize costs of actions to all waterway interests. The process is considered to be one of accommodation, and all interests are expected to make some sacrifices in times of shortage.

10. Relative Influence and Impact of Non-Navigation Users. Recreation activity has developed extensively around Lake Sidney Lanier. Periods of heavy power generation have caused significant short-term fluctuations in the level of the reservoir, and complaints from recreation interests have been numerous.

Recreation activity is not an authorized project purpose of the Sidney Lanier project. However, the Corps

recognizes the importance of the substantial recreation investments around Lake Sidney Lanier and considers costs and benefits to recreation as well as authorized purposes when determining operating policy.

Navigation and power generation interests also appear to have recognized that recreation merits consideration, as these interests have not opposed past operating policies giving some consideration to recreation. Navigation interests are highly organized and voice complaints and suggestions through the Tri-Rivers Association. Navigation interests have generally recognized the needs of other waterway interests, and the Tri-Rivers Associations opinions are considered constructive.

One other consideration is the rapid development of the Atlanta metropolitan area, which could put further pressures for power generation, industrial process water, domestic and commercial water supply, and even recreational development upon the ACF system. Studies are currently underway to determine future needs for the area, including the Metropolitan Atlanta Water Resources Study now in its sixth year. This is a study commanding substantial attention, and its findings may determine allocations for large amounts of water resources funds.

The EPA has recently ordered Atlanta to return all water withdrawals from the Chattahoochee back to the ACF Basin instead of the present method employed, which transfers water to other basins. Due to this return requirement, downstream navigation will not be significantly adversely affected by reduced flows downstream due to inter basin transfers.

However, increased withdrawals from Buford to support Atlanta's growth may change the management of Buford if a structural remedy is not utilized. Water supply requirements are provided by constant flows, while Buford generates hydropower as a peaking operation. A reregulation dam has been proposed to smooth out surges six miles below Buford. A serious alternative would be to cut peak power output from Buford to allow more compatible releases. The Corps is currently studying both of these proposals.

Further development of the basin's waters for navigation, flood control, and hydropower may damage some

of the environmental resources and natural beauty of existing streams. A number of rare plants, fisheries resources, and wildlife habitat could be damaged or altered by this development. According to the National Water Assessment, however, restriction in development of the water resources could result in some loss in economic growth to the area. These concerns will be the subject of the lengthy discussion for proposed projects.

11. Conclusions. Future flow problems on the ACF will be much the same as they are at the present. During dry years, there will be stretches of several months when there will be insufficient water to maintain a nine foot channel. By 2000, the probability and the length of these occurrences will be increased slightly. However, if Atlanta is forced to return to the ACF basin the water it is presently withdrawing from the ACF and discharging to the Ocmulgee basin, would be increased slightly. This will reduce the impact of increasing consumption.

The uses most affected by low flows on the ACT are hydropower, recreation, and navigation. Past Corps decisions have used economic criteria for apportioning water among the three during droughts. In the future the basis for these criteria may change and some of the users may be less satisfied with the resulting decision.

A number of alternatives to alleviate present and future problems exist for the ACF basin.

Water demand management can be an important tool for improving efficiency of water consumption and allowing more water to pass downstream. The Corps is essentially limited to an informational and advisory role.

Interbasin transfers are not being seriously considered, especially in light of the EPA decision to force Atlanta to return Chattahoochie withdrawals to that same river. It is doubtful that such a proposal would be economically justifiable to cover a seasonal low flow situation.

Increasing storage capacity would allow more flexibility to schedule releases. Buford's storage could be increased, but this may cause problems for recreation users. New sites for reservoirs have been identified, but stron opposition to construction does not make this an alternative in the near future.

Reservoir management will continue to be the most important Corps tool. Growth in needs for all uses will require maximum benefits to the competing interests.

Increased dredging at the lower portion of the Apalachicola would assist navigation. However, Florida environmental regulations currently limit this activity.

12. Critical Factors and Data Gaps. The final decision concerning the location of the wastewater discharge for Atlanta could have an effect on base flows on the ACF system. However, the magnitude of this effect will be small.

The most important factor impacting navigation water supply on the ACF is the recreation usage of Buford Reservoir, which requires that water be retained in the lake. In evaluating economic trade-offs during droughts, the Corps has also placed a relatively high value on the recreation use. If a critical low flow period occurred during the peak recreation season, operational flexibility of the lake would be severely limited. This management approach has serious implications for commercial navigation that should be evaluated before a crisis develops.

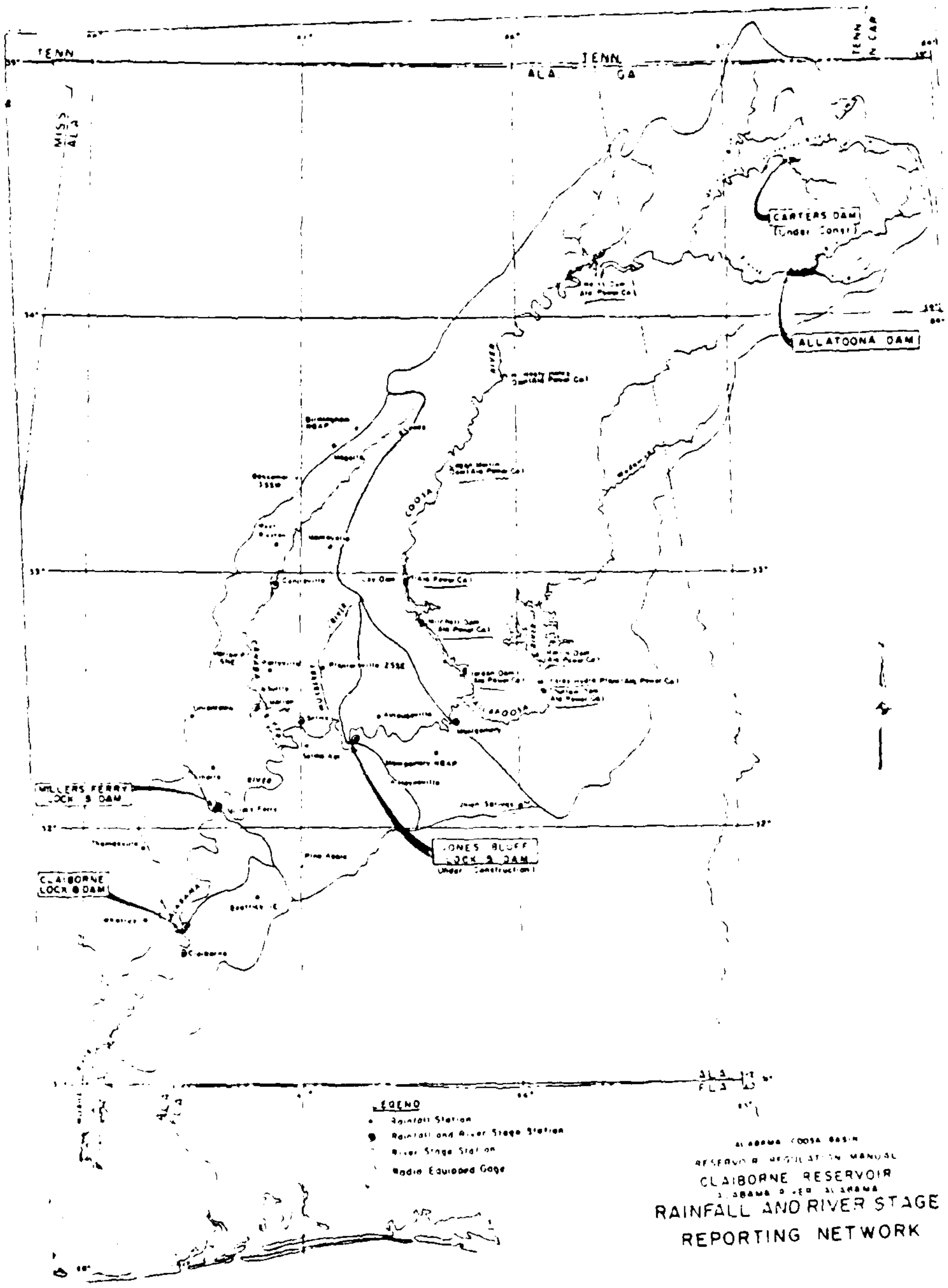
(f) Region 12: Black Warrior-Tombigbee and Alabama-Coosa River Systems

Within this river system, (See Figure III-Q), the Alabama Coosa was identified as a potential problem area. This is similar to the ACF situation described above, where it is basically an extension of existing low flow problems into the future.

1. Present Water Supply. Average streamflow in the Alabama River, under 1975 conditions, at Clairborne, Alabama is 21,800 MGD as shown in Appendix A, and minimum flows are in the fall. During an average year, minimum monthly flows are in the fall. During an average year, minimum monthly flows are 16% of the maximum month. During drought conditions, minimum monthly flows are 14% of the maximum month.

Figure III-Q

Alabama-Coosa Basin



2. Present and Future Water Demand. Existing and projected consumptive water demands are found in Appendix A, Table A-22. The table also presents annual average demand from 1975 to 2000 in five year increments. The only use which varies significantly between average and drought conditions is irrigation demand which is a very minor use in this basin. (See map in Figure III-Q).

The most significant categories of water consumption affecting Segment 36 are industrial uses and power plant cooling. In the year 2000, industrial uses are expected to be responsible for 51% of all water consumption in the Alabama-Coosa River system, and power plant cooling for 29%. The respective figures for 1975 in these categories were 31% and 19%. The next largest year 2000 projected category of water consumption is domestic and commercial, with a 14% share, down from 36% in 1975.

The high growth of water consumption forecasted for industrial uses warrants consideration of trends in this area. Water has not been considered scarce in the past due to the high precipitation levels in the Alabama-Coosa Basin, and water access for industrial users has not been a problem as long as effluent standards are met. The major concern of many industrial entities is energy consumption, and the placing of new processes or modifications to existing processes will stress energy conservation. This emphasis is likely to reduce the water withdrawals, but the effects upon water consumption may not be significant as energy-saving processes have been seen to both increase and decrease water consumption. Most opinions tend to be on the side of slightly-lowered consumption.

Power plant cooling is also a significant category of water consumption in the Alabama-Coosa Basin, and trends in this area have been to move towards plants requiring more water consumption per unit of output as cooling requirements become more extensive. Environmental pressures to reduce the temperatures of cooling water cycled back to the source water system have led to the construction of more cooling tower facilities that significantly add to water consumption requirements, as opposed to flow-through system formerly more popular. Research into new types of cooling systems could influence water consumption requirements up or down, depending upon which designs reach the implementation stage. Combination air-water cooling systems are in advanced design stages

and could greatly reduce water consumption requirements. Close-cycle cooling systems are also being seriously considered, and implementation would greatly decrease water withdrawals but increase consumption. Water consumption has not usually been an important factor in consideration of poor plant design.

3. Future Water Availability. The amount of water availabile in the Arkansas Basin in 2000 is shown in Figure III-R. The figure is a graph of monthly flows for drought and average occurrence and 1975 and 2000 conditions. The year 2000 flows were calculated by subtracting the forecast water consumption increase from the existing supply. In projecting the impact of consumption upon streamflow it was assumed that all consumption would be from renewable sources by 2000.

In the graph, some months actually show an increase in supply while others show significant decreases. This is a result of increased peaking of water demand for irrigation in the future. It should also be noted that during a drought in the year 2000, water demand exceeds supply in July and August.

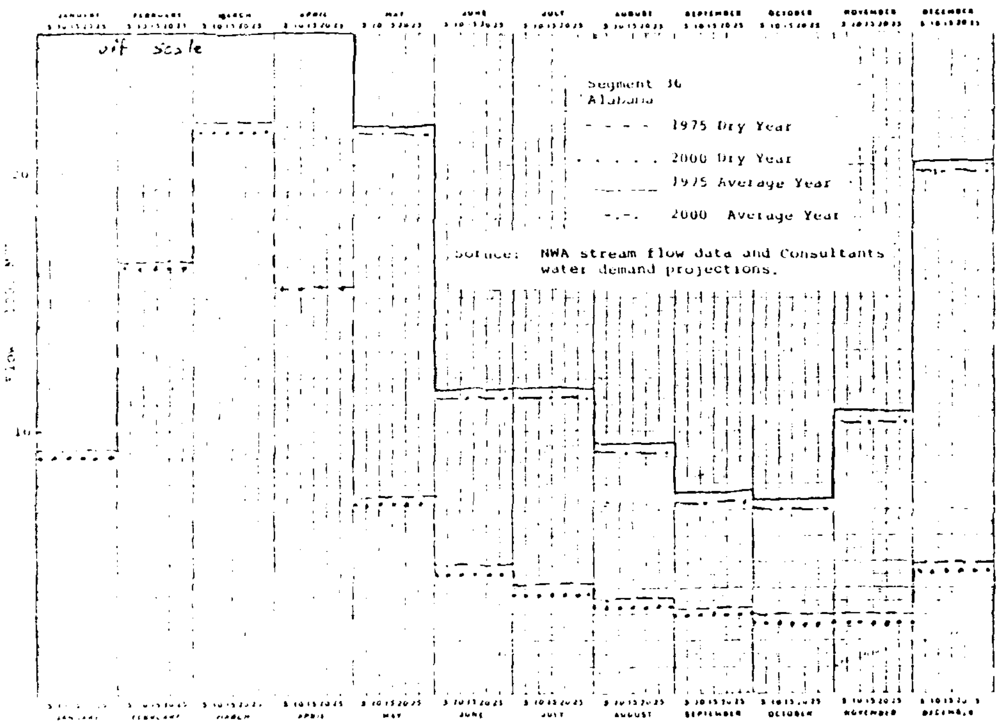
4. Depth Relationships to Navigation. The major operator in terms of tonnage on the Alabama River is Radcliff Materials. They operate with specially designed low draft towboats of five and one-half feet to six feet that facilitate their operations in dredging and hauling gravel. For other commidities seven and one-half feet in considered the minimum depth due to economic considerations. Daily stage fluctuations due to hydropower peaking operations are common on the Alabama River.

High flows annually produce stages that submerge locks and prevent navigation for short periods of time on the Alabama River. Flood flows, however, do not produce velocities that hinder navigation on the Alabama or Coosa.

A depth-discharge relationship, according to the Corps, is roughly descriptive but not rigid. Depths during low stages are provided as a function of rising or falling water levels, and operators adjust according to other boat operators' indications of having touched bottom. Navigation "on the bottom" is possible on the Alabama River because of its soft bottom composition. The average relationship is given below as measured at Claiborne and is

Figure III-R

Alabama-Coosa River, Stream Flow Data



considered reasonably valid for low flow conditions in the fall.

Depth (feet)	Discharge (cfs)	(MGD)
10	12,500	8,000
9	11,000	7,000
8	9,500	6,000
7	8,000	5,000
6	6,500	4,000

5. Historic Problems for Navigation and Corps Actions. The two most recent years, 1978 and 1979, provide an example of hydrologic extremes, 1978 being a very dry year and 1979 exhibiting large flood flows. At least 10,000 cfs are required to maintain a nine foot channel below Claiborne dam. Beginning in early July 1978, and continuing through November, there were 119 days of (seven percent of the time) of flow less than 10,000 cfs. During the period of September 22 to November 26, the flow never exceeded 8,000 cfs, and stages fell to as low as five feet. Commercial navigation ceased entirely during parts of this period. While 1978 was a year of drought conditions, it is rare that flows are continually maintained above 10,000 cfs, especially during the critical months of September through November.

The following spring, 1979, high rainfall in March and April caused flood flows which closed lock operations on three occasions and exceeded turbine capacity on five occasions. The lock was closed for a total of 22 days. However, according to the shipping companies, they are capable of navigation over the spillway at Claiborne and Millers Ferry. Bridge clearances, reduced by high stages, closed operations entirely for a few days during 1979. High flows which have caused the closing of the locks have occurred during 14 of 44 years analyzed. The 1979 year was the highest sustained period of flood flows on record.

Low flows may occur anytime after the spring flood season, but they are usually most severe from September through November. It is only during above average runoff years that a nine-foot channel has been maintained during the fall. During drought years lowered depths have caused the barge companies to resort to light loading and to occassionally cease operations.

The effect of high velocities and/or flows below the authorized depths do affect navigation interests. According to the Corps, high velocities may reduce the efficiency of th two operators but they never preclude navigation. Low flows occur in the free flowing stretch of the river below Claiborne Lock and Dam. Claiborne operates as a reregulating pondage project to compensate for inaccuracies in inflow estimates and unanticipated changes in releases from the APC upstream power plants. However, effectiveness of this reregulation would be improved if a schedule of releases were known.

6. Future Navigation Flow Problems. The effects of future low flow problems upon navigation are depicted in Figure III-S. This graph is the same as Figure III-R with the addition of horizontal lines at the flows which define depths of nine, eight and seven feet. Only drought conditions are shown on the graph because there is more than enough water during an average year. However, during a drought year, the natural stream flow will be less than the amount required for a nine foot channel during seven months. Future increases in consumption are not expected to be significant since the number of deficient months is the same for 1975 and 2000.

7. Reservoir System. Storage of water in the basin occurs in nine reservoirs along the Coosa and Tallapoosa Rivers. The following uses are important to operations:

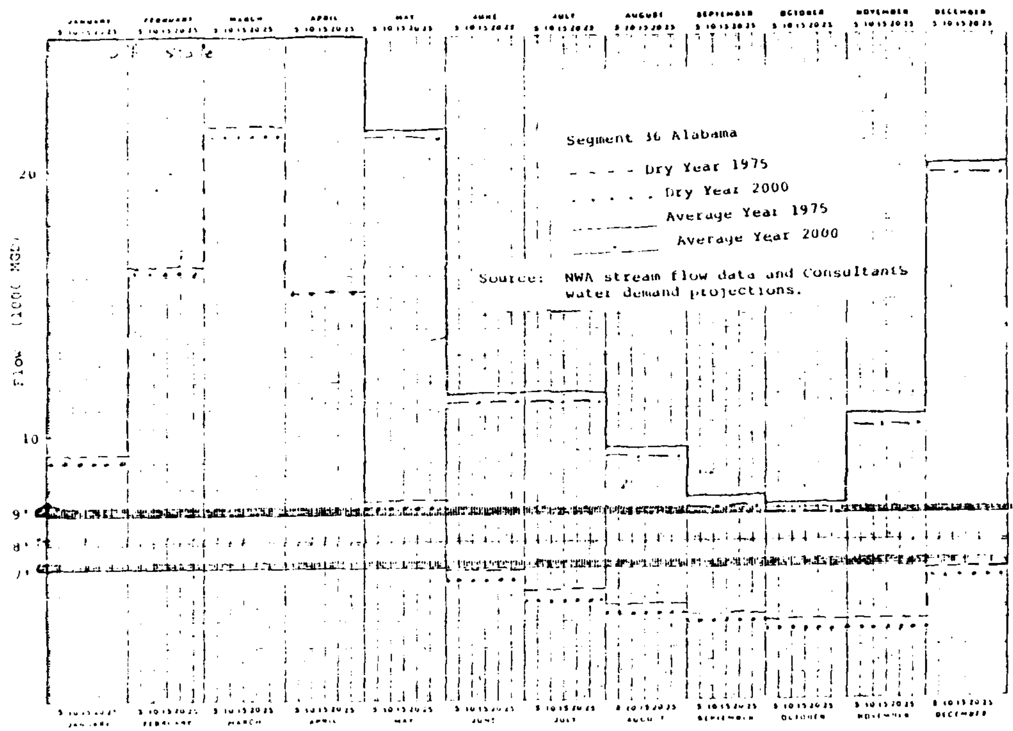
(a) Flood control. The Corps incorporates flood control storage requirements, an authorized use, and incorporates them into a regulation manual. The owner of the reservoirs, the Alabama Power Company (APC), maintains pool levels in concurrence with these directives.

(b) Power Generation. This authorized use is essentially in the hands of the APC, which generally uses storage to provide peaking power for the Southeastern grid.

(c) Navigation. The Corps is authorized to maintain a navigation channel from Montgomery to the mouth of the Alabama River.

Figure III-S

Alabama-Coosa River, Low Flow and Depth Relationship



(d) Water Quality. At Altoona, a continuous release of 210 cfs is maintained to satisfy "Riparian Rights," but this is probably not a legal requirement. At Carter's Dam, a pumped storage facility, there is a requirement to maintain 240 cfs below the reregulation dam for water quality, and this may be a legal requirement. There is an agreement between the Corps and the State of Alabama to maintain 65000 cfs below Claiborne Lock and Dam.

(e) Recreation. While not a directly authorized use, recreation development has been occurring around APC projects.

The actual wording of the authorization document is that the Alabama-Coosa River system will be developed "for navigation, flood control, power generation and other purposes," according to an item in Section 2 of the 1945 River and Harbor Act. Furthermore, the authorization allows for "modifications for the purpose of increasing the development of hydroelectric power."

8. Storage Availability and Present Releases. There are approximately 980,000 acre feet of operational storage in the Alabama River Basin. This is four percent of the average annual flow and seven percent of the drought annual flow. Most present releases are made for the purpose of hydropower generation although they are loosely coordinated with navigation requirements.

9. Planning Structure and Corps Control. Hydropower operations are determined through the interactions of four organizations - the Corps, Alabama Power Company, Southeast Power Administration (SEPA), and the Federal Energy Regulatory Commission (FERC). The FERC is the licensing body and grants authorization for specific projects to the Alabama Power Company. The wording of the agreement states, in effect, that the Corps will determine the needed releases for purposes other than hydropower. The releases required for navigation have been supplied by the Corps in the form of a memorandum of understanding and the Corps has specified these release requirements on a volume of discharge per week basis. The Alabama Power Company usually operates on a peaking schedule in accordance with load. Load is controlled by the SEPA for the

entire Southeastern region by balancing demand with available power generation.

Power generated by units on the Alabama River are managed on a system basis with units on the Apalachicola-Chattahoochee-Flint (ACF). Although the two rivers are hydrologically separate, the projects are managed by the Mobile District on the basis of load requirements for not only the two river basins, but also under consideration of the power grid for the entire Southeast region under SEPA jurisdiction. Thus, an analysis of the flow conditions at a particular project only partially determines the releases for hydropower, since the releases are balanced with the total system requirements.

The Alabama Power Company (APC) has a working agreement with the Corps for the operation of five hydropower projects. The agreement stipulates that a minimum of 32400 day-second-feet will be released from the APC reservoirs over a seven-day period. In order to meet peaking load requirements during the low flow season the APC will often release the entire amount over the five-day working week and practically zero over the weekend. Occasionally, single day releases may constitute up to one third of the total requirement. The generating units of the APC are all remote-controlled and are automated to function according to load requirement. Therefore, even the APC is not aware of the precise scheduling of their releases on an hourly basis.

A major constraint to planning is the lack of control the Corps has over the APC releases. Discussions are underway to change the APC release patterns from a weekly schedule to a daily schedule. This would dampen the waves of flow passing through the system. Alternatively, it would be possible to schedule a nine-foot channel for five days a week and a seven-foot channel for two days a week or some combination thereof. This would allow the waterway users more reliability in scheduling their operations in comparison to present conditions.

The Corps presently compensates for APC releases by drawing down pools behind Jones Bluff and Millers Ferry dams on weekends. But fluctuations in APC hydropower operations prevent the Corps from maximizing the benefits of releases from points where the Corps has control.

10. Relative Influence and Impact of Non-Navigation Users. Since the upstream power projects are privately owned and operated on a hydropower peaking schedule, some conflict exists between hydropower and navigation interests, as detailed in the "Planning Structure and Corps Control" section. The Corps must negotiate changes in operations or effectively reregulate surges to improve navigation planning, as the Corps does not have the authority to directly control APC releases.

Recreation interests have been placing pressure upon the APC and the Corps to manage reservoirs with more consideration of the detrimental impacts to recreation of pool fluctuations and release surges. Recreation development along reservoirs is not extensive at this time, but growth is expected to be significant. As the number of recreation users increases, pressures for management considerations can be expected to be more effective.

The Corps meets with users to allow consideration for regular needs and special requests. In this way, the operation of the Alabama-Coosa system maximizes hydropower generation while adverse effects to other project purposes are minimized.

11. *Conclusions*. Future flow conflicts on the Alabama River should be generally the same as they are today. Increases in consumptive use of water are not significant. However, existing natural flow shortages and timing conflicts with hydropower will continue to adversely impact commercial navigation. Emphasis on energy production will excerbate this conflict.

As previously mentioned, the Corps is negotiating with the APC in an attempt to gain release scheduling more advantageous to navigation activity. It is possible that the APC could be compensated for loss of peaking power, and this is being considered in the present discussions.

Reservoir operations can be used to save water for the seasonal low flow periods. Holding more water in upstream projects on a seasonal basis would require APC cooperation.

Expansion of reservoir capacity could be utilized to save water for low flow periods. This can be accomplished through allowing more storage in present projects or construction of new upstream structures. The latter

alternative would face substantial opposition. Interbasis transfers have not been seriously considered for the Alabama-Coosa River Basin.

Demand management would be possible to a limited extent, providing water consumption could be stressed as a design criterion. Industrial and power plant users could also be given incentivies to use less consumptive processes. However, while demand management will reduce average daily consumption, it would not be a substantial remedy to the seasonal flow problem.

(g) Region 16: Great Lakes

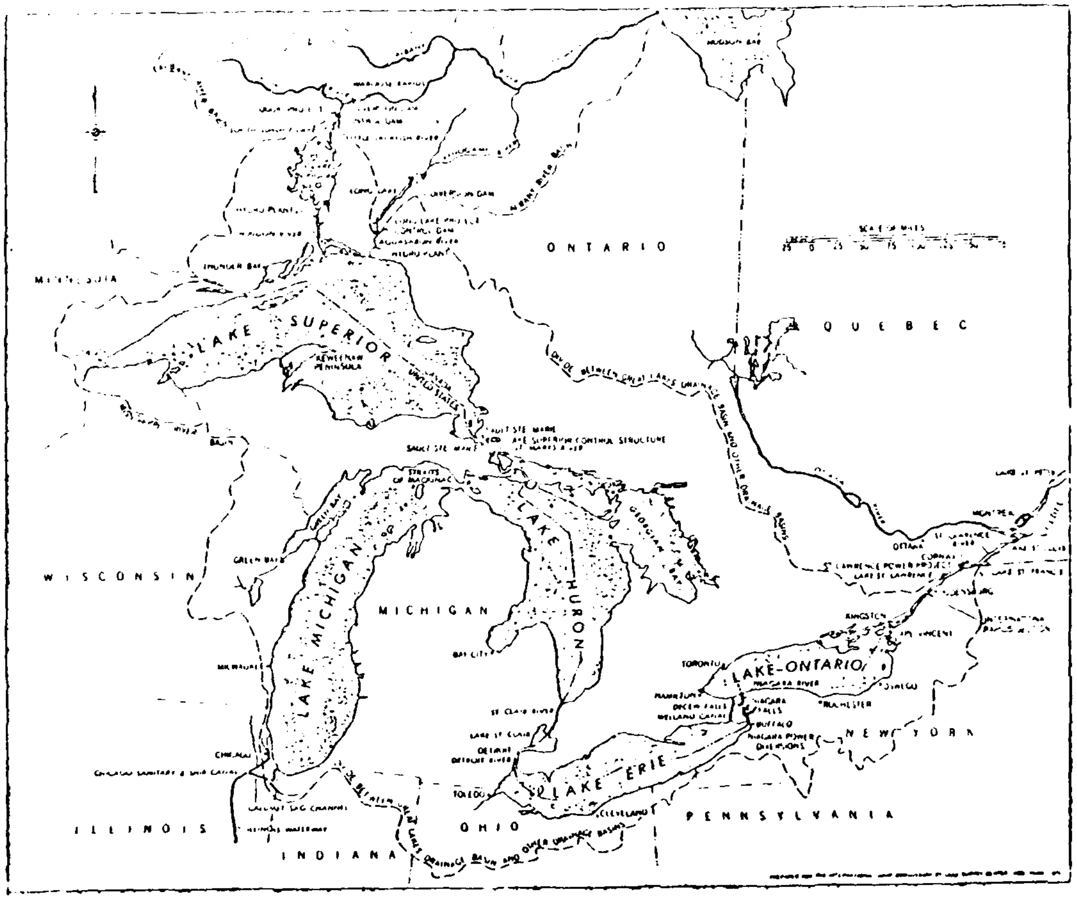
The Great Lakes (see Figure III-T) were given special examination here because they are sensitive to long-term changes in levels which effect channel depths. The discussion below was limited to question of whether or not future water consumption would have a significant impact on lake levels.

1. Factors Impacting Water Levels. The vast water surface area of the Great Lakes combined with the restricted capacities of their outflow channels make them the finest naturally regulated fresh water system in the world. The usual range of water levels from winter lows to summer highs seldom exceeds one and one-half feet. However, there are still much larger variations in the lake levels caused by natural conditions. Periods of deficient or excessive precipitation lasting several years can cause the average monthly lake levels to be two to three feet below or above the long-term average. Strong storm winds and sharp differences in barometric pressure have caused water levels to rise as much as eight feet on one side of Lake Erie and two feet at some locations on Lake Ontario. Other natural phenomena causing fluctuations of water levels are ice jams and the growth of aquatic weeds in the connecting channels which, reduce discharge from upstream lakes.

In view of the magnitude of these fluctuations the effects of human activities on lake levels are generally small. These effects can be divided into two categories. There are structures and management procedures which attempt to reduce the extent of fluctuation without

Figure III-T

Great Lakes St. Lawrence River Drainage System



changing the long term average. This is usually a benefit to navigation and will not be evaluated in detail here.

There are other human activities which change the long-term lake levels. These changes are very important to commercial navigation and can be caused by diversions to or from the Great Lakes, regulation structures, navigation structures, and consumption of water.

2. Diversions. A number of works have been constructed which transfer a limited amount of water into or out of the Great Lakes basin. The operation of the Long Lac diversion commenced in 1939. It diverts water into Lake Superior from the Albany River Basin that would normally flow into the Hudson Bay. The diverted water is used to generate electricity at a power plant on the Aquasabon River. Since 1940, an average of 1400 cfs (910 MGD) has been diverted into Lake Superior.

The Ogoki Diversion Project also transfers water from the Albany River Basin into Lake Superior. The purpose of the Ogoki Project is to generate power at three hydroelectric plants on the Nipigon River. It began operation in 1943 and has diverted an average of 4000 cfs (2600 MGD), although the actual amount has varied from 0 to 16,000 cfs (10,400 MGD). Together, the Lona Lac and Ogoki diversions represent seven percent of the average outflow from Lake Superior. They have raised the level of Lakes Michigan-Huron by 0.37 feet and raised Lake Erie 0.23 feet. During the high water periods in the early 1950s and middle 1970s (caused by excessive precipitation) the Ogoki diversions were reduced or stopped for several months each year. The change was made voluntarily by Ontario-Hydro in order to provide relief to shoreline residents from high lake levels.

There has been a connection between Lake Michigan and the Mississippi River Basin since the 1800s. Water is diverted through the Chicago River and the Chicago Sanitary and Ship Canal. The primary purpose of the diversion is to dilute the sewage effluent from the Chicago Sanitary District and carry it to the Mississippi River. The water also supports navigation on Sanitary and Ship Canal and generates electricity at two small hydro plants on the Illinois Waterway. By a decree of the United States Supreme Court, the diversion is limited to a maximum of

3200 cfs (2080 MGD). The diversion lowers Lakes Michigan-Huron by a total of 0.23 feet and Lake Erie by a total of 0.14 feet.

3. Regulation. At the present time only Lakes Superior and Ontario have regulation structures. The operation of these structures is established in a set of rules issued by the International Joint Commission (IJC). The purpose of the rules is to provide levels and flows that result in generally beneficial conditions for all lake users without unacceptable adverse effects on any one interest.

The natural outflow of Lake Superior has been modified ever since 1822 when a raceway and sawmill was constructed in the St. Marys Rapid (see Figure III-U). The existing set of control gates were approved by the IJC in 1914 and begain operation in 1921. The gates were required because the power canals, which were built between 1893 an 1902, increased the amount of water that could be discharged from Lake Superior. The IJC's original orders stated that the compensating works and power canals should be operated so as to maintain the level of Lake Superior "as nearly as may be" between the elevation of 600.5 and 602.0 and in such a manner as not to interfere with navigation.

Present operation of the power canals and control structures is under "1979 Modification of the Rule of 1949." The objective of this regulation scheme is to maintain Lake Superior levels between 598.4 and 602.0. The purpose is to balance benefits among the upstream and downstream users. There should not be any additional adverse impacts on navigation.

The outlet of Lake Ontario contains a number of navigation and hydropower projects as shown in Figure III-V. Collectively known as the St. Lawrence Seaway and Power Project, they enable 25 foot draft ships to traverse between the Great Lakes and the Atlantic Ocean, provide 1,824,000 kilowatts of hydropower generating capacity, and allow for control of levels of Lake Ontario. In 1960, the IJC put into operation Regulation Plan 1958-A. The plan has been updated and modified several times since then. The current plan 1958-D came into use in 1963. The objective of all of the plans is to provide all possible relief to upstream and downstream riparian owners during periods of high flow, and to navigation and power interests during

Figure III-U

Lake Superior Outlet

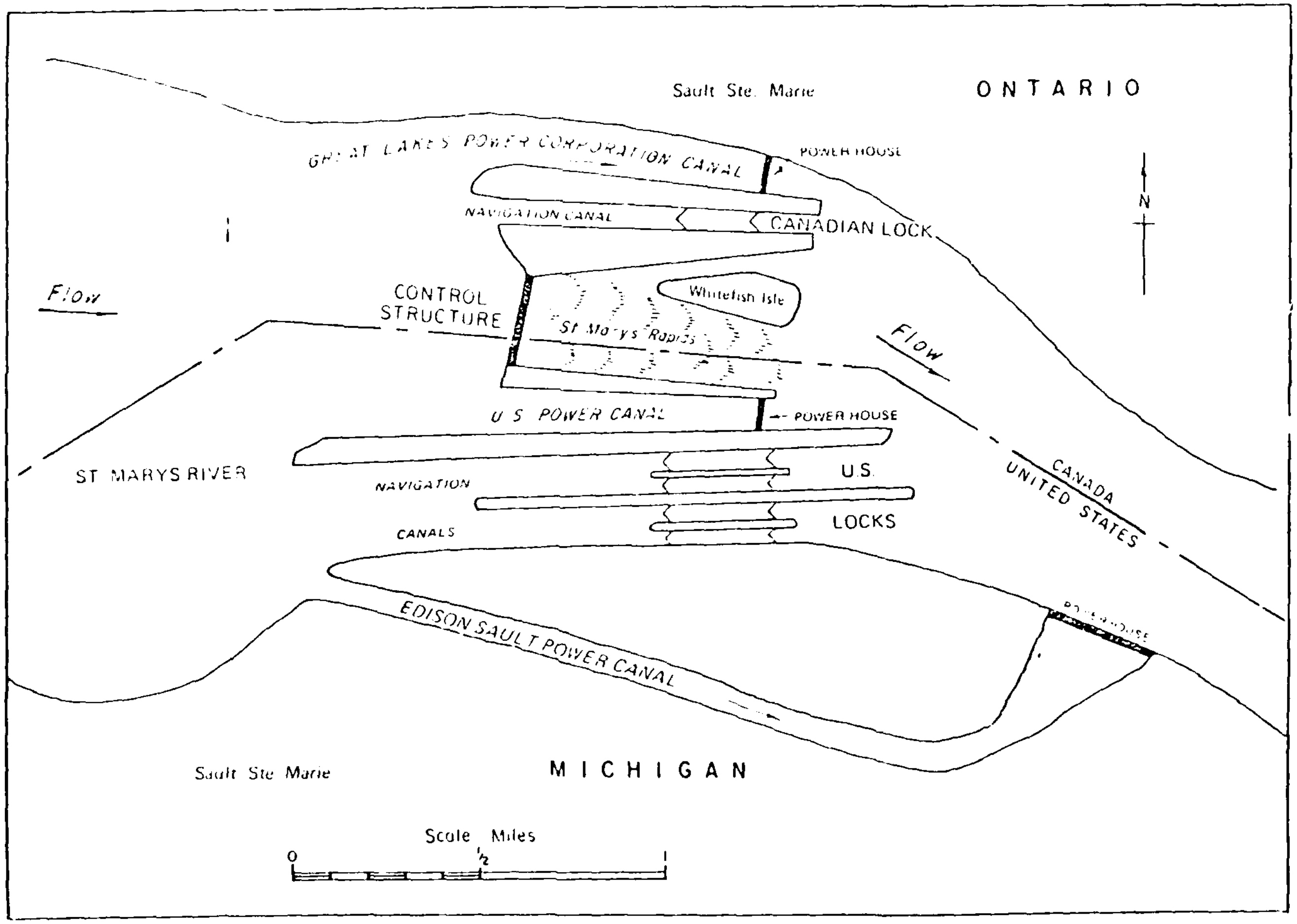
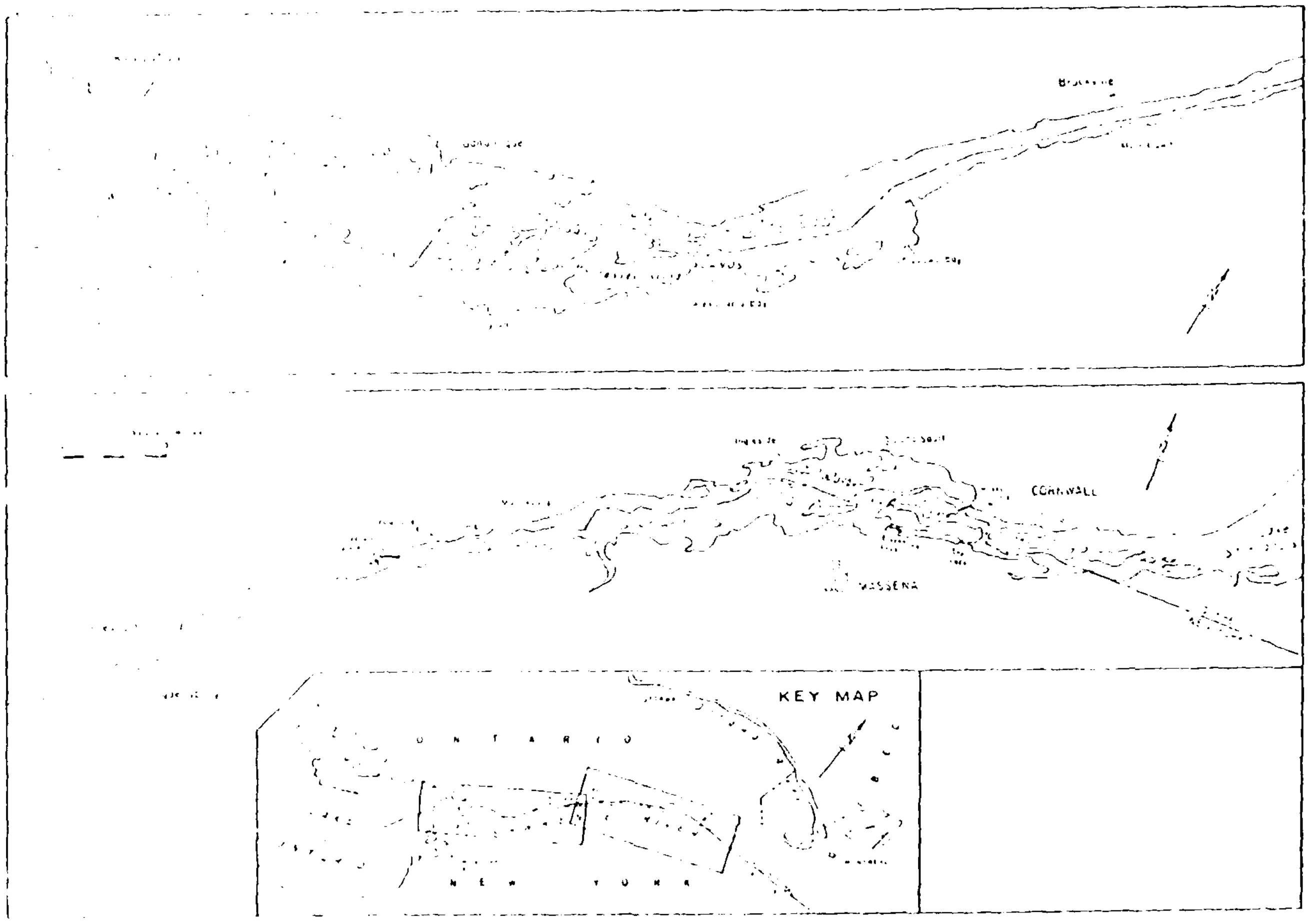


Figure III-V

Lake Ontario Outlet



periods of low flow. As with the control of Lake Superior, the IJC attempts to achieve a balance of benefits among all of the users.

The IJC has recently completed a study evaluating further regulation of Lakes Superior and Ontario and construction or regulating structures for Lakes Michigan-Huron and Erie. The results of the study indicate that the costs of any additional regulation would exceed the benefits. Therefore, no increases in man-made regulation are expected.

4. Navigation. Several navigation projects have impacted water levels of the Great Lakes. The channels of the St. Clair River out of Lake Huron in their natural state were so obstructed by sand bars that navigation and flow were constrained. In 1933, the channel was dredged to 25 feet and in 1962 it was deepened to 27 feet. The effect of this dredging was to increase flow out of Lakes Michigan-Huron and to decrease their levels by 0.59 feet.

The Welland Canal is the navigable link between Lakes Erie and Ontario, bypassing the Niagara River. It presently diverts an average of 7000 cfs (4550 MGD) for navigation and for generation of power at DeCew Falls Power Plant. By increasing the natural discharge from Lake Erie, the Canal has lowered the level of Lake Erie by 0.32 feet and Lakes Michigan-Huron by 0.10 feet.

The New York State Barge Canal System diverts an average of 700 cfs (450 MGD) from the Niagara River, but this amount is too small to impact lake levels.

5. Consumption. Water withdrawn for consumptive uses permanently reduces lake levels. The consumptive use of water in any one lake basin not only reduces the net water supply to that lake, but also reduces the net water supply to all downstream lakes.

Existing and future water consumption in the United States from each of the Great Lakes has been estimated and is included in Appendix A Tables A-24 through A-28. Most of the water consumption in the Great Lakes basin is primarily the result of industrial uses and secondarily of power plant cooling and mineral handling.

Table III-11 is a summary of United States water consumption increases for all of the lakes and the cumulative effect. The Consumptive Use Survey of the Great Lakes Basin estimates Canadian water consumption as approximately 24% of United States consumption. On that basis, total Great Lakes water consumption is given in Table III-12.

6. Navigation Impact. The impact of increasing water consumption upon Great Lakes levels can be roughly estimated from a set of factors used in the regulation of Great Lakes water level study. The dynamic nature of the system may cause an additional adjustment (on the order of 10%) as the lakes stabilize in response to water supply changes but these factors are sufficient for an initial estimate. The coefficients for each lake and the forecast lake level changes are shown in Table III-13.

7. Conclusions. Increases in water consumption in the Great Lakes Basin over the next 20 years should not have any impact on lake levels or commercial navigation. Great Lakes water levels will continue to be dominated by natural factors and large diversions. No additional human regulation of the lakes is foreseen. Water resource conditions for navigation will remain as they are at the present time.

(h) Conclusion on Water Availability in the United States Waterway System

Over the next 20 years there will be water availability problems for navigation on three free-flowing waterways; the Alabama in Region 12, the ACF in Region 11, and the Missouri in Region 6. None of the canalized rivers or segments will have shortages of water for navigation because the required water volumes for lockages are relatively small. However, in three of the western rivers such as the Arkansas (segment 24) the Ouachita (segment 25) and the Red (segment 25) there may be conflicts between other water users as supplies become constrained. The causes, effects and potential solutions of these problems will vary significantly between river basin, and navigation will have only a minor role.

Table III-11

United States Water Consumption from the Great Lakes (MGD)

Lake	1975 Conditions		2000 Conditions		Increase from 1975 to 2000		Cumulative Increase	
	Average	Drought	Average	Drought	Average	Drought	Average	Drought
Superior (Seg. 49)	133	133	198	199	65	66	65	66
Michigan-Huron (Seg. 47-48)	1020	1037	1781	1819	761	782	826	848
Erie (Seg. 46)	1321	1325	1500	1506	179	181	1005	1029
Ontario (Seg. 45)	119	121	256	260	137	139	1142	1168

SOURCE: Summary of Tables III-45 through III-47.

Table III-12

Total Great Lakes Water Consumption (MGD)

Lake	1975 Conditions		2000 Conditions		Increase from 1975 to 2000		Cumulative Increase	
	Average	Drought	Average	Drought	Average	Drought	Average	Drought
Superior	165	165	246	247	81	82	81	82
Michigan-Huron	1265	1286	2208	2256	943	970	1024	1052
Erie	1638	1643	1860	1867	222	224	1246	1276
Ontario	148	150	317	322	169	172	1416	1448

SOURCE: Summary of Tables III-43 through III-48.

Table III-13

Great Lakes Level Responses to Water Supply Changes

Lake	Level Change		Drought Water Consumption Increase 1975 to 2000 (MGD)	Forecast Lake Level Change (feet)
	Feet per 1000 cfs	Feet per 1000 MGD		
Superior	0.00296	0.00456	82	-0.0004
Michigan-Huron	0.00208	0.00320	1052	-0.0003
Erie	0.00951	0.01465	1276	-0.019
Ontario	0.0125	0.01925	1448	-0.028

SOURCE: Tables III-49 and Regulation of Great Lakes Water Levels, Appendix B, Lake Regulation.

Conflicts in the western rivers will be caused by increases in consumptive use of water for irrigation. Irrigation already accounts for approximately 90% of all water consumption in these areas and almost all of the projected increase in water consumption is for irrigation. Demands on surface water will also be magnified as farmers are forced to abandon groundwater mining for irrigation water due to cost, availability, or new regulations.

The Alabama and Appalochicola Rivers presently experience navigation problems due to low flows. Increases in water consumption in these basins will not be large but will further complicate efforts to resolve these problems.

The effects of low flows upon navigation will vary depending on the river basin. Operators on the Alabama and ACF are already confronted by this problem. These rivers have a soft substrate and shippers are accustomed to operating "on the bottom" during low flows. They also have euipment which is suitable for light loading. In the Missouri Basin as water shortages become severe, the effect will be to shorten the navigation season. By 2000, the possibility exists, that a severe, prolonged drought could shut down navigation for over a year. Normally, however, the enormous upstream storage on the Missouri provides virtually complete flow control during the navigation season.

In the Middle Mississippi the effects of increased water consumption upon navigation are unpredictable. Navigation depths in these segments are controlled more by sediment loads than by instantaneous flow rates. Increased water consumption may agravate shoaling problems by increasing flow extremes during periods of high sediment load or it could reduce problems by limiting peak flows. Further study of this problem area is recommended.

The capability within a segment to respond to low flows is highly variable. In the Missouri Basin there is enough storage to contain 387% of the annual drought flow. However, on the Alabama-Coosa storage space amounts to only seven percent of the annual drought flow.

Usage of available storage space in most basins is limited by institutional arrangement established for project control. Except for the Missouri and Arkansas Basins, there is little integrated system management. Most management is done on a project by project basis often because there is no single authority with responsibility for water resource management in a basin. There may be several organizations (federal, state or local, private or public) each with its own projects and each with different purposes. It may not be possible or desirable to have a single authority with water resource control but the present fragmented approach in most basins inhibits total system management, and may reduce the total benefits generated by Corps projects.

Whatever management system is utilized, the final resolution of any conflict will be strongly influenced by the priorities of the various water users. On the Missouri River, navigation is fourth out of six stated purposes. In the other basins priorities are not this explicit, but most impoundment projects do not give a high priority to navigation needs. As water shortages become more acute these unstated priorities will significantly reduce available options for maintaining commercial navigation.

It is also apparent that the tools available for policy decisions within reservoir management have not been developed to the same level as the technical tools for physical management of the reservoir systems. The most progress in this direction to date has been on the Arkansas where rough but useful relationships have been developed to show the links between flows and various uses (e.g., flood control and navigation damage functions). These rough measures must be improved to provide a basis for better decision-making.

In the future reservoir management decisions will need to be guided by better understanding of short-term impacts on other users. Management information and basin-wide water resource management guidelines relating to day-by-day decisions will have to be improved for effective decision-making in at least the eight systems described above.

IV - RESERVOIR MANAGEMENT AND INSTREAM FLOWS

This section examines the relationships between navigation, instream flows and reservoir management on the national waterway system. In several regions there are relatively complex interactions which must be examined on a case by case basis as described below.

METHODOLOGY

The methodology used for this analysis was to examine each reservoir system and its operation in some detail as case studies, where there was an identified flow management issue affecting navigation, or where there were specifically-authorized navigation releases. Minimum flow requirements, both legal and traditional, were also identified through a telephone survey for each waterway segment.

(a) Case Study Selection

Field studies were carried out for a set of case study segments. These segments were selected based on the following criteria:

Primary Criteria

1. At least one of each type of potential conflict or interaction with navigation.

2. Magnitude of potential conflict or interaction.

3. Diversity of factors affecting conflict or interactions (segment type, level of commercial navigation).

Secondary Criteria

1. Diversity of uses.

2. Diversity of location.

The primary criteria were selected for identifying the most important interactions and influencing factor. The secondary criteria were selected for identifying other potentially influential factors and more complex interactions and for gains in statistical explanatory value concerning all segments.

The procedure for segment selection using these criteria was as follows:

1. Develop a set of indices which will describe the segment characteristics and the interaction.

2. Select those segments which correspond to the primary criteria.

3. Where there is a choice between segments which meet primary criteria, use secondary criteria for the selection.

4. Test whether the subset of segments selected in representative of all segments and of segments with significant conflicts along key dimensions (segment type, level of commercial navigation, number of purposes and uses, geographical location).

This procedure was followed as closely as the data would allow. The data on magnitude of conflict (Index 6) were primarily verbal communication from field or telephone interviews, or from data in the NWS Inventory, and did not lend to fine distinctions. Therefore, the magnitude of each identified interaction could only be gauged as to whether or not it was significant. Where it was significant, it appears on Table IV-1, as an identified conflict. The other indices allowed more clear cut distinctions, as defined below.

The characteristics of the segment selected based on the above procedure were compared with the characteristics of all segments and of all segments with conflicts. The comparison showed that there is little difference between them, except that the number of authorized and actual uses is greater in the sample segments, as well as in the conflict segments, compared to all waterway segments. The indices used for selection (see Table IV-1) are given below.

Table IV-1

Indices for Selection of Significant Segments

WRS Segment Name	Authorized Purpose	Present Uses	Segment Type	Level of Commercial Navigation	Location	Identified Problem	Identified Beneficial Uses
1. Upper Miss. R.	NRB	NWRBAFC	S	H	NCD	(RB), FC	BL (RB)
2. Lower Miss. R.	N	NB	S	H	LMVD		
3. Middle Miss. R.	N	NB	F	H	LMVD		
4. Lower Middle Miss. R.	NF	NF	F	H	LMVD		
5. Upper Lower Miss. R.	NF	NFW	F	H	LMVD		
6. Lower Miss. R.	NF	NF	F	H	LMVD		
7. Miss. R.-Baton Rouge, La	NFWRBQC	N	F	H	LMVD		
8. Miss. R.-New Orleans to Gulf	NFWRBQC	N	S	H	LMVD	SW, FC	
9. Illinois Waterway	NPO	NRBQWL	S	H	NCD		
10. Missouri	NFRFIHIW	NFRFCIZW	F	L, H	MRD	RA, FC	(FW)
11. Upper Ohio River	NFRQHD	NFWRBFW	S	H	ORD		
12. Middle Ohio River	NRBD	NRBD	S	H	ORD	RB, SR	
13. Lower Ohio R.-Three	N	NWBOCH	S	H	ORD		
14. Lower Ohio R.-Two	N	NWBOCH	S	H	ORD		
15. Lower Ohio R.-One	N	NWBOCH	S	H	ORD	BL	
16. Monongahela River	NFOH	NFWRBF	S	H	ORD		
17. Allegheny River	N	NWBF	S	L	ORD		
18. Kanawha River	NRBD	NB	S	H	ORD		
19. Kentucky River	N	NWRBCH	S	L	ORD		
20. Green R.-Barren R.	N	NWBC	S	L	ORD	HP	
21. Cumberland River	NFOH	NFWRBH	S	H	ORD	HP	
22. Upper Tennessee R. & Clinch R.	NFH	NFWRBH	S	H	ORD	HP	
23. Lower Tennessee R. to Ohio R.	NFH	NFWRBH	S	H	ORD	HP	
24. Arkansas, Verdigris White & Black R.	NFWRFW	NFWRFW	S	L	SWD	FC, BL, HP	(RB, FW)
25. Ouachita, Black & Red R.	NRBFI	N	F&S	L	SWD	CU	
26. Old & Atchafalaya R.	NFWRFQ	N	F	H	LMVD		
27. Baton Rouge-Morgan City Bypass	N	N	S	H	LMVD		
28. GIWW West (Eastern Section)	NFI	NF	C	H	LMVD	SW	
29. GIWW West (Middle Section)	N	NB	C	H	SWD, LMVD	SW	
30. GIWW West (South Section)	N	NB	C	L	SWD		
31. GIWW East (West Section)	N	F	C	H	LMVD/SAD		
32. GIWW East (East Section)	NFBR	N	C	L	SAD		
33. Florida Gulf Coast	NB	NRBFE	C	L	SAD		
34. Houston Ship Canal	N	NB	C	H	SWD		
35. Black Warrior River	NB	NR	S	H	SAD		
36. Alabama Coosa River	NFP	NFRBFW	F&S	L	SAD	BL, HP, (FW)	
37. Tennessee-Tombigbee Waterway	NB	NB	S	NA	SAD		
38. Apalachicola, Chattahoochee Flint R.	NFRH	NFRFW	F&S	L	SAD	(RB), BL, (FW)	
39. Florida/Georgia Coast	N	NRBFEC	C		SAD		(BC)
40. Carolinas Coast	NO	NBD	C	H	SAD	(RB), (BC)	(BC)
41. Chesapeake & Delaware Bays	NFRBD	NFRBD	C	H	NAD	SW	
42. New Jersey/New York Coast	NB	NRBD	C	H	NAD		
43. New York State Waterways	NFWRBI	NFWRBIE	S	H	NAD	BL	
44. Upper Atlantic	NFBYOE	NFRBE	C	L	NED		
45. Lake Ontario & St. Lawrence Seaway	NRBE	NRBQCH	G	H	NCD	CU, (RB)	
46. Lake Erie	NRB	NWFBQ	L	H	NCD	CU, (RB)	
47. Lake Huron	NRBFH	NBFH	L	H	NCD	CU, (RB)	
48. Lake Michigan	NRBE	NBE	L	H	NCD	CU, (RB)	
49. Lake Superior	NB	NB	L	H	NCD	CU, (RB)	
50. Puget Sound	NRB	NRB	C	H	NPD	RB, SW	
51. Upper Columbia Snake Waterway	NFIH	NFRBIH	S	H	NPD	(FW), HP, FC	(RB)
52. Lower Columbia, Snake, Willamette R.	NRFO	NB	S	H	NPD	(FW), HP, FC	
53. Oregon Washington Coast	NF	NFB	C	L	NPD		
54. Northern California	NBD	NBO	C	L	SPD		
55. San Francisco Bay	NB	NB	C	H	SPD	(RB), SW	
56. Central South California	NF	NB	C	H	SPD		
57. Southeast Alaska (Panhandle)	NBDE	NBDE	C	L	NPD		
58. South Central Alaska Coast	N	NB	C	H	NPD		
59. West & North Coasts of Alaska including Aleutians	N	NB	C	L	NPD		
60. Western Pacific including Hawaii, Guam, and American Samoa	N	N	C	H	POD		
61. Caribbean, including Puerto Rico & Virgin Islands	N	NBFRE	C	H	SAD		

NOTES:

( ) = not used for sample selection purposes here

Key for Segment Indices

I. Location
- LMVD = Lower Mississippi Valley Division
- MRD = Missouri River Division
- NAD = North Atlantic Division
- NCD = North Central Division
- NPD = North Pacific Division
- ORD = Ohio River Division
- POD = Pacific Ocean Division
- SAD = South Atlantic Division
- SPD = South Pacific Division
- SWD = Southwest Division

II. WRS Segment Name

III. Authorized Purposes
- N = Navigation
- F = Flood Protection
- W = Water Supply
- R = General Recreation
- B = Boating Recreation
- A = Aesthetics
- F = Fish & Wildlife
- E = Environmental
- Q = Water Quality
- I = Irrigation
- C = Cooling Water
- L = Low Flow Augmentation
- H = Hydroelectric Power
- D = National Defense
- O = Other

IV. Uses
Same letter as purposes

V. Segment Type
- S = Channelized
- F = Free Flowing
- C = Coastal
- G = Inland
- L = Great Lakes

VI. Level of Commercial Navigation
- H = Greater than 10 million tons transported annually
- M = Between 2 and 10 million tons transported annually
- L = Less than 2 million tons transported annually

VII. Identified Problem within Segment or Beneficial Use
- R = Recreational Boating
- BE = Beach Erosion
- BC = Beach Creation
- CU = Consumptive Use
- SW = Salt Water Intrusion
- FW = Fish & Wildlife Habitat
- HP = Hydropower Sites & Peaking Problems
- BL = Releases for Low Flow Augmentation
- FC = Releases for F [illegible]

1. Location. The Corps of Engineer Division is specified in which the segment is located. This indicator is the most pertinent for Corps data reference.

2. Authorized Purposes. Each NWS analytic segment was assigned those purposes appearing on the NWS Inventory for any subsegment which falls within the analytic segment. Therefore, the indicated purpose may be for only one or more subsegments, but not necessarily for the entire segment. (It should be noted that the boundaries of the segments defined in the NWS Inventory do not always correspond to the boundaries of the analytical segment. There are also subsegments where no purposes are identified, which is probably an error in the data.) This indicator is the best reference for intended use in project design.

3. Segment Type. The segments were distinguished in the following manner:

(a) Free flowing.

(b) Slack water (canalized).

(c) Coastal.

(d) Great Lakes.

(e) Islands.

These distinctions are the key differences between segments for navigation water use.

4. Present Uses. These data were obtained from the NWS Inventory Sheets. (The same data limitations as noted under authorized uses apply here.) This indicator is the best available for actual uses on a system-wide basis.

5. Level of Commercial Navigation. The level of commercial navigation was summarized in terms of three ranges of total commodity movement based on data shown on NWS Map No. 6. This indicator was the best summary in one number for traffic data.

6. Identified Conflicts and Beneficial Uses. The types of conflicts or beneficial uses occurring in

navigation projects were identified through field interviews with Corps personnel or in the NWS Inventory (constraints only) where they were significant for commercial navigation. These were the only system-wide sources available for identifying conflicts, prior to the case studies.

For each selected segment (see Table IV-2), a detailed case study was carried. Particular emphasis was placed on the actual patterns of releases in past low and high flow years.

(b) Integrated Instream Flows

For each of the analytic segments with significant instream water uses, a minimum stream flow envelope was prepared for both an average and a dry year. The minimum streamflow envelope incorporates all of the complementary instream water uses into one annual hydrograph. In theory, each use (fish and wildlife, hydropower, etc.) is placed on the graph and one line is drawn which is a curve of the maximum values, over time, of instream demand. If the requirements of this curve (the instream flow envelope) are satisified, then all instream uses should be satisfied since they are all less than the constructed curve, and they are all complementary. Because the instream flows which are being evaluated in this task are all minimum required flows, the instream flow envelope represents the extreme minimum streamflow independent of navigation releases.

The minimum stream flow envelope is used to analyze the complementary aspects of other water uses which augment stream flow. The envelope for each segment was compared with navigation needs on each of the selected segments.

(c) Detailed Reservoir Management Data

Further analysis of the management practices of each of the four reservoirs with navigation releases was carried out. These data identified the probability of

Table IV-2

Data on Selected Segments for Reservoir Instream Flow Analysis

NWS Region	NWS Segment Name	Authorized Purpose	Present Uses	Segment Type	Level of Commercial Navigation	Identified Conflict	Reservoir with Navigation Releases
1	Upper Mississippi	NRB	NWRBAFC	S	M	FC	X
6	Missouri	NPRFIHZW	NPRFQIZW	F	M	RL,FC	X
7	Monongahela	NPQH	NPWRBF	S	H	RL	X
7	Cumberland	NPQH	NPWRBH	S	M	HP	
9	Arkansas	NPWRFH	NPWRFH	S	M	HP	X
11	ACF	NPRH	NPRFH	F and S	L	RL,FW	X
12	Alabama-Coosa	NPR	NPRBFH	F and S	L	RL,HP,FW	
18	Upper Columbia	NPIH	NPRIH	S	M	HP,FC,FW	

NOTES: Authorized Purposes

N = Navigation
P = Flood Protection
W = Water Supply
R = General Recreation
B = Boating Recreation
A = Aesthetics
F = Fish & Wildlife
E = Environmental
Q = Water Quality
I = Irrigation
C = Cooling Water
G = Low Flow Augmentation
H = Hydroelectric Power
D = National Defense
Z = Other

Uses
(Same letter code as purposes)

Segment Type
S = Channelized
F = Free Flowing
C = Coastal
I = Island
L = Great Lakes

Level of Commercial Navigation
H = Greater than 20 million tons transported annually
M = Between 2 and 20 million tons transported annually
L = Less than 2 million tons transported annually

Identified Problem Within Segment

FW = Fish and Wildlife habitat
HP = Hydropower surge or peaking problems
RL = Releases for low flow augmentation
FC = Releases for flood control

alternative pool levels and the details of reservoir management in each case. These data were not included in this report since its level of detail is too extensive for presentation here. All conclusions from this analysis have been included in the following discussions.

CASE STUDIES OF RESERVOIRS WITH NAVIGATION RELEASES

Five reservoirs or reservoir systems were identified with specifically-authorized navigation releases. These were: the Upper Mississippi (Region 1); the Missouri (Region 6); the Monongahela (Region 7); the Arkansas (Region 9); and the ACF (Region 11). Each of these is examined below.

(a) Upper Mississippi River (Region 1)

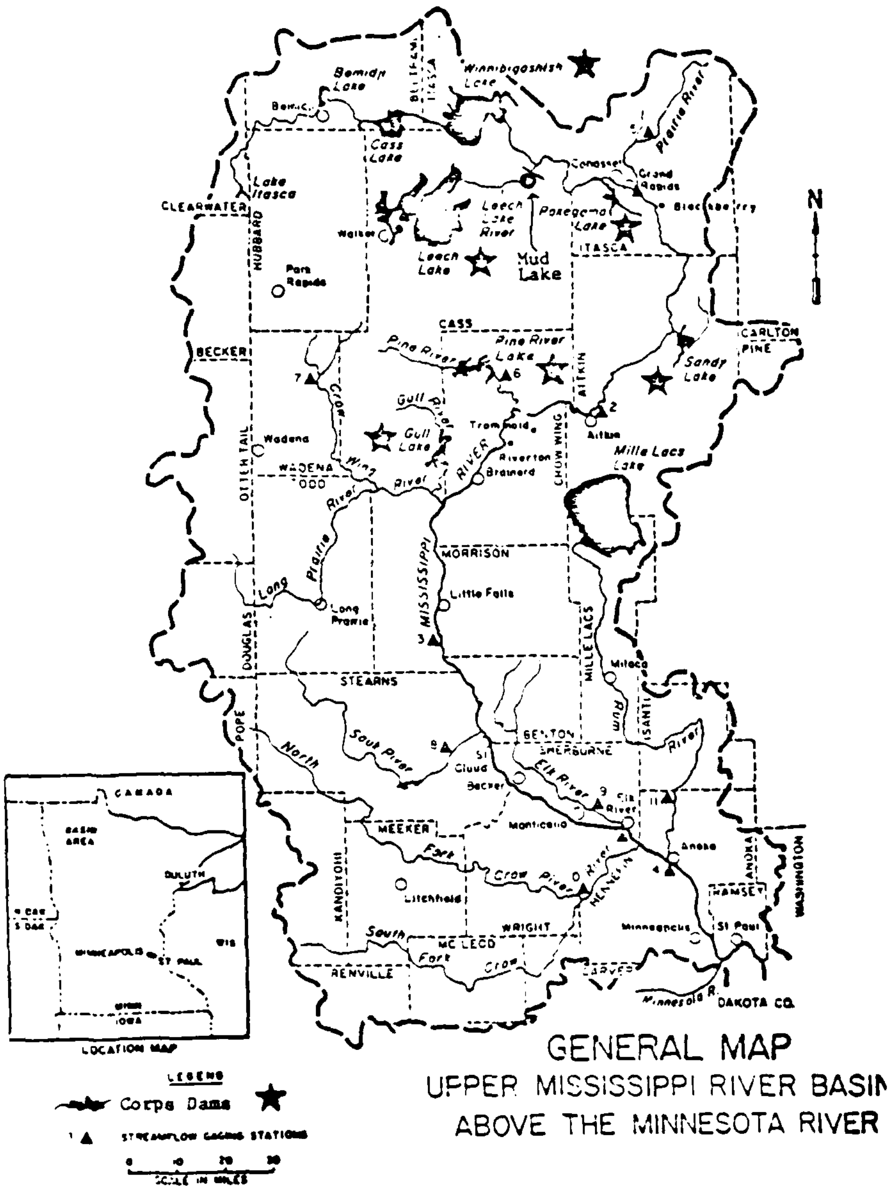
1. Topography. The headwaters area of the Mississippi River is located in north central Minnesota and is defined as the Mississippi watershed above Minneapolis (see Figure IV-A). It covers approximately 19,400 square miles. The headwaters area is relatively flat and includes numerous lakes and large areas of poorly drained marsh.

2. Climate. The climate of the headwaters basin is characterized by warm to hot summers and long severe winters, often with snow cover from November through March. Mean annual snowfall is 49.5 inches and annual precipitation is 24.3 inches. Normally the winter months, December through February are the driest months while the greatest amount of precipitation occurs during June and July.

3. Reservoirs. The headwaters area of the Mississippi River contains six federal reservoirs. Two of the reservoirs, Winnibigoshish and Pokegama, are located on the main stem. The other four, Leech, Sandy, Pine and Gull are on tributary streams. The six projects were originally constructed for the purpose of aiding navigation between St. Paul and Lake Pepin on the Mississippi River. Construction of the first dam, Winnibigoshish, was

Figure IV-A

Upper Mississippi River Basin



begun in 1881 and completed in 1884. The sixth and final dam, Gull, was completed in 1911.

Under present operating procedures the six lakes have a total storage capacity of approximately 1.6 million acre-feet. About 80% of this capacity is contained in Winnibigoshish and Leech Lakes.

4. Navigation. In its original condition prior to any improvements, the navigable channel of the Mississippi River at low water had a natural depth of only three feet or less. In 1878, Congress authorized a 4 1/2 foot channel on the Mississippi River from St. Paul to the mouth of the Ohio River. To insure that this channel could be maintained, the Corps undertook a study of the headwaters area in order to determine the feasibility of constructing a series of dams which could regulate river flow for the purpose of improving navigation in the upper Mississippi basin.

Originally, it was proposed to construct 41 reservoirs in the headwaters region. The first dam, Winnibigoshish, was authorized, when a pilot project and construction began in 1881. It was put in operation in 1884. Three other dams, Pokegama, Leech and Pine were completed between 1883 and 1886. With these four reservoirs in operation, it was found that enough water could be stored to improve navigation at and below St. Paul, so that the initial plan to build 41 reservoirs was abandoned. The other two projects, Sandy and Gull, were built later and did not significantly impact navigation.

It was not possible to obtain data on the releases which were required to support navigation in the Upper Mississippi Channel that period of history.

In 1930, Congress authorized a nine-foot channel on the Mississippi from the mouth of the Illinois River to Minneapolis. Channel dimensions were to be maintained by a system of locks and dams supplemented by dredging, where necessary. Since completion of the nine-foot project with the associated locks and dams, the need for water to support navigation has been greatly reduced. As a result, the operation of the headwater reservoirs has changed to meet different needs. Releases from the six lakes have not been required for navigation.

5. Reservoir Management. In 1888, Congress directed the Secretary of War to establish regulations governing the operation of the six headwater lakes. General regulations were first established in 1889 and later formally modified in 1931, 1935, 1944 and 1945.

The 1889 regulations developed by the War Department were not specific as to elevation or flow. These regulations directed the Government officer in charge of dam operation to store "the surplus over the ordinary low-water supply to the reservoirs and so much of said low-water volume as may not immediately needed for any purpose below any dam," until the safe limits of the reservoirs were reached, or until water was needed for navigation downstream of the dams. The expressed purpose for storing water in the lakes was to provide a stable and sufficient water stage for navigation in the downstream navigable reaches of the Mississippi River and on the downstream reaches of the tributary streams on which the dams were located. Although the 1889 regulations did not specify operating levels, certain operating limits were developed and used by the officer in charge. These levels, through usage, became known as "original operating limits," and were as follows:

Lake	Original Operating Limits in Stage (feet)
Winnibigoshish	0 to 14.2
Leech	0.5 to 5.24
Pokegama	4.5 to 12.0
Sandy	0.6 to 11.0
Pine	1.3 to 18.5
Gull	1.0 to 7.0

During the 1930's, the nine-foot navigation project, including locks and dams, was constructed along the Mississippi River, greatly reducing the need for navigation water. The Secretary of War issued a series of new regulations for the six lakes between 1991 and 1945, in response to the demands of local interests and the changing requirements of navigation. The general effect of these regulations was to raise the lower operating

limits for each lake. The operating limits for the 1931 to 1945 regulations are shown below:

Lake	Original Operating Limits in Stage (feet)
Winnibigoshish	6.0 to 14.2
Leech	1.0 to 5.24
Pokegama	6.0 to 12.0
Sandy	7.0 to 11.0
Pine	9.0 to 15.0
Gull	5.0 to 7.0

Between 1961 and 1963, the State of Minnesota made a comprehensive study of the headwaters region culminating in recommendations for changes to the operating procedures for the lakes. The state recommendations could not be formally adopted without congressional direction, but in actual practice, the recommended stage heights and minimum flows are usually followed. The effect of these changes has made the lakes primarily recreation facilities with a small amount of flood control. During the winter, the lake levels are lowered slightly and then raised in the spring to reduce flood runoff. In the summer, the Corps tries to maintain a constant level in the lakes for recreation. These operating stages are shown below:

Lake	Ordinary Stage Stage (feet)	Ordinary Spring Stage (feet)	Ordinary Summer Stage (feet)
Winnibigoshish	6.0 to 14.2	8.0	10.0 to 10.5
Leech	1.0 to 5.24	0.5	1.3 to 2.2
Pokegama	6.0 to 12.0	6.0	8.75 to 9.25
Sandy	7.0 to 11.0	7.0	12.75 to 13.25
Pine	9.0 to 15.0	11.0	12.75 to 13.25
Gull	5.0 to 7.0	5.0	6.0 to 6.25

6. <u>Effect of Reservoir Management on Navigation</u>. Without any other data, it is difficult to determine the impacts upon navigation of the six headwater lakes prior to the 1930's. Since the original plan for 41 reservoirs was never completed, the desired effect must have been achieved with the original six reservoirs.

After construction of the locks and dams, the lakes have been used less for navigation and more for recreation. In 1945, Congress passed a resolution calling

for a comprehensive study of the headwater lakes, which should make recommendations on their future management. This study has only been funded within the last several years. Phase I which is the Plan of Study, has now been completed and Phase II is now beginning. The results of these studies will determine the future uses for the Mississippi headwater lakes.

7. Conclusions. The Mississippi headwater lakes were originally authorized and constructed to support navigation on the Upper Mississippi River. They apparently served the purpose for about 30 to 40 years, until the construction of a system of locks and dams from St. Paul down to the mouth of the Ohio River. Because the lakes were no longer critical to navigation, their management has changed in response to other needs, although the original authorization has not changed.

At the present time, a study is in progress to recommend future plans for the lakes. It is expected that the study will propose some sort of recreation-oriented management similar to the existing plan of operation. It is possible that the authorization may be modified at that time.

As evidenced by their present form of operation, the lakes are no longer necessary for commercial navigation. Therefore, there are no real conflicts between navigation and other uses over lake management. This is not expected to change in the future.

(b) Missouri River
(Region 6)

1. Topography. The Missouri River is formed by the confluence of the Gallatin, Madison and Jefferson Rivers in southwestern Montana and flows generally east and south for 2,460 miles to join the Mississippi River near St. Louis. The total drainage area of the basin is 529,350 square miles, which is approximately one-sixth of the total land area of the contiguous United States. The Rocky Mountains, with elevations over 14,000 feet, form the western boundary of the basin. Except for the Black Hills in South Dakota and the Ozark uplift in southern Missouri, all of the basin to the east of the Rocky Mountains may be considered as plains country. These high plains range from 2,000 feet at their eatern edge to 4,000

to 6,000 feet where they give way to slopes of the Rocky Mountains.

2. Climate. Weather within the basin is widely variable, ranging from alpine environs in the high western mountains to continental climates in the southeast. Normal precipitation ranges from 35 inches or greater in the Rocky Mountains to about 10 to 15 inches in the Great Plains and rises to about 36 inches in the Ozark Highlands. Much of the precipitation in the upper portion of the basin falls as snow in the high mountains, producing a distinct period of spring runoff. In other portions of the basin, large rainfall events can occur and produce local flooding. Ice is common in the river system with much of the upper portion of the Missouri River being completely frozen during portions of the year.

Prior to construction of the main stem reservoirs, (see Figure IV-B), the typical regime along the Missouri was a low level of flow during the winter, increasing with the melt of the plains snow in March and April, and the mountain snow in May and June. This peak season was followed by a decline during the hot, dry, late summer and fall, to another winter low. The basin was highly susceptible to both extended severe droughts and damaging floods.

3. Reservoirs. With the construction of the main stem reservoirs, the fluctuations in river flow are primarily the result of human control. The six main stem reservoirs (Fort Peck, Garrison, Oahe, Big Bend, Fort Randall and Gavins Point) have a total storage capacity of about 75 million acre-feet, which is equivalent to three times the average annual flow of the Missouri past Sioux City, Iowa. The storage volumes and allocated purposes for each of the dams are shown in Table IV-3.

The priorities for operating the main stem reservoirs are described in the Missouri River Main Stem Reservoir Regulation Master Manual:

First, flood control will be provided for by observation of the requirement that an upper block of storage space in each reservoir will be vacant at the beginning of each year's flood season, with evacuation scheduled in such a manner that flood conditions will not be significantly aggravated, if at all possible. (This space is available for annual regulation for flood control and

Table IV-3

Main Stem Storage on the Missouri River
(1000 acre-feet)

Project	Exclusive Flood Control	Annual Flood Control and Multiple Use	Carryover Multiple Use	Inactive	Total
Fort Peck	1,000	2,700	10,900	4,300	18,900
Garrison	1,500	4,300	13,400	5,000	24,200
Oahe	1,100	3,200	13,700	5,500	23,500
Big Bend	60	117	270	1,730	1,907
Fort Randall	1,000	1,300	1,700	1,600	5,600
Gavins Point	62	97	195	358	17
TOTAL	4,722	11,714	39,200	18,488	74,730

all multiple purpose uses, but should be vacant at the beginning of each year's flood season.)

Second, all irrigation, and other upstream water uses for beneficial consumptive purposes during each year will be allowed for. This allowance also covers the effects of upstream tributary reservoir operations, as anticipated from operating plans for these reservoirs or from direct contact with the operating agencies.

Third, downstream municipal and industrial water supply and water quality requirements will be provided for.

Fourth, the remaining water supply available will be regulated in such a manner that the outflow from the reservoir system at Gavins Point provides for equitable service to navigation and power.

Fifth, by adjustment of releases from the reservoirs above Gavins Point, the efficient generation of power to meet the area's needs, consistent with other uses and power market conditions, will be provided for.

Sixth, insofar as possible, without serious interference with foregoing functions, the reservoirs will be operated for maximum benefit to recreation, fish and wildlife.

Within this framework, some flexibility is available in order to respond to specific demands. Twice yearly, the representatives of eight federal agencies and ten states meet as the Coordinating Committee on Missouri River Main Stem Reservoir Operations. They review operation of the system and make recommendations for the Annual Operating Plan. This plan becomes a guide for scheduling releases during the following year. The Reservoir Control Center prepares the plan and implements its provisions on a day-to-day basis. Committee members are advised if it becomes necessary to depart from the plan provision due to unforeseen circumstances.

4. Normal Navigation Operation. The Missouri River navigation project extends from the mouth of the Missouri, upstream for 735 miles to Sioux City, Iowa. Authorized channel dimensions are nine feet deep by 300 feet wide. It is a free flowing river which has no locks or dams on the navigable channel (see Figure IV-B).

Figure IV-B

Missouri River Basin

1978

MISSOURI RIVER BASIN

In order to maintain authorized dimensions, certain minimum flows are required. Operating experience indicates that flows of 25,000 cfs at Sioux City and Omaha; 31,000 cfs at Nebraska City and 35,000 cfs at Kansas City are the minimum that will permit navigation. To reduce groundings, dredging or other problems, the Corps has decided that it is desirable to maintain flows above these minimums, when system storage reserves are adequate. Therefore, target flow levels 6,000 cfs greater than the minimum flows specified above have been established as the "full service" level for navigation. When full service flows are maintained, heavier barge loadings are possible.

These minimum and full service flows are maintained by releases from Gavin Point, the lowest of the main stem reservoirs. Normally, navigation releases from Gavins Point are only scheduled for eight months of the year because ice cover does not permit vessel movement the other four months. If there is sufficient water, and ice is not a problem, the navigation season will be extended ten days after the normal closing date (December 1st). The average monthly Gavins Point release rates needed to provide minimum navigation flows are shown in Table IV-4.

Table IV-4

Gavins Point Release Rates for Minimum Navigation Service (1000 cfs)

March	22.8
April	22.8
May	24.8
June	24.0
July	26.7
August	28.2
September	28.5
October	27.5
November	27.5
Average	25.9

The average seasonal release rate from Gavins Point required for navigation has varied from 22,100 cfs to as high as 33,700 cfs. Monthly requirements have ranged from 13,000 cfs less than the values in the table to 8,000 cfs greater than the tabulated values.

5. Drought Operations. During drought conditions, there may not be enough water in the main stem reservoirs to serve other water users and still release enough water for an eight month full service navigation season. The Division Engineer normally has two possible responses to low water conditions.

The first response is to reduce the flow rate from full service to minimum service. The decision to reduce the service level is made based on the amount of storage which is available as shown in Table IV-5. Intermediate service levels are defined by interpolation.

Table IV-5

Relation of Service Level to System Storage

Date	System Storage (million acre-feet)	Service Level
March 15	54.5 or more	Full service
	46.0	Minimum service
July 1	59.0 or more	Full service
	50.5 or less	Minimum service

In the event of an extended drought, there will not be enough water to maintain a full navigation season even at the minimum flow level. It is the Corps policy then to reduce the season's length. Table IV-6 shows the relationship between the season length and the amount of available storage.

There are other possible policy responses to drought conditions such as maintaining season length and further reducing depth or increasing dredging to maintain depth. However, the options which are presently followed seem to work best under the existing conditions.

6. Reservoir Management. In order to evaluate the impacts on various water users of the priorities and operating procedures of the main stem reservoirs, a hydrologic model of the system was prepared. On a monthly basis it calculated storage, inflow and releases and evaluated the amount of power generated and the service provided to navigation.

Table IV-6

System Storage vs. Navigation Season Length

System Storage on July 1 (million acre-feet)	Season Length (weeks)
41	32
40	31
39	30
37.5	29
36.5	28
35	27
33.5	26
32	25
30	24
27.5	23
25	22

A recent model study utilized the 1970 level of depletions as the base year and then simulated additional depletions for 1980, 2000 and 2020. For each of the years, reservoir storage was adjusted for sedimentation, and a range of offstream consumptive withdrawals were estimated. Hydrologic input for the model was 75 years of historical stream flow records. The result was a 75 year simulated history of operation for each selected year and range of depletions.

This study can be utilized to forecast future service to navigation under various assumptions. By relating a scenario to a year and a depletion the probability of different levels of service to navigation can be estimated.

7. Effect of Reservoir Management on Navigation. Two criteria were devised for measuring the impact of other water users and the reservoir management system upon commercial navigation. The first related a year and an assumed depletion to the "Average Season Service Level." The Average Season Service Level is a combined measurement of the flow rate (full service, minimum service, or in between) and the duration of that flow rate. Full service releases for a full eight month season are arbitrarily defined as a season service level of 35,000 cfs. A ten-day extension to the season could result in a service level greater than 35,000 cfs. A season service level of 29,000 cfs could correspond to a minimum service release

for eight months, a full service release for 6.6 months, or other combinations. To achieve the full service rating requires the full service flow for eight months at each of the control points: 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City, and 41,000 cfs at Kansas City (see Figure IV-C). The results of the model for a 75 year historic period simulation are shown in Table IV-7.

Table IV-7

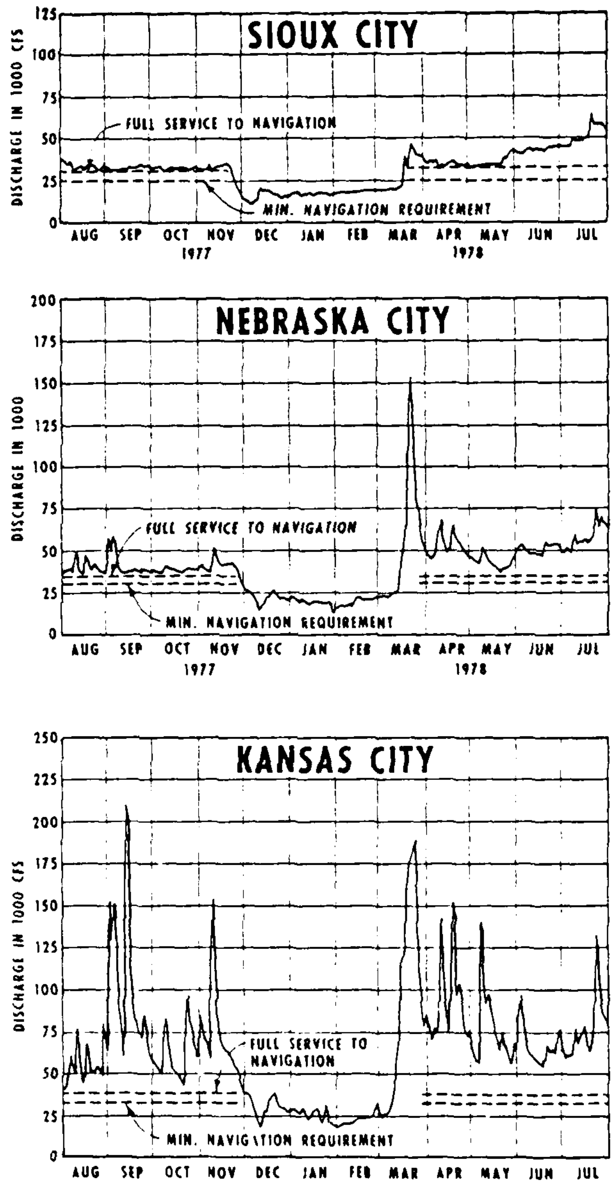
Level of Service Simulation

Year	Average Annual Depletions Over 1970 Level, Above Sioux City (1000 acre feet)	Projected Average Annual Season Service Level (1000 cfs)
1970	0	32.9
1980	991	31.8
1980	1019	31.7
1980	1191	31.6
1980	1393	31.3
2000	2589	29.3
2000	3129	28.7
2000	3669	27.8
2000	4994	26.0

The second criteria for evaluating navigation releases is the season length. As less and less water is available for navigation, there is not enough to maintain a full season even at the minimum service level. At this point the length of the navigation season is reduced. For each of the selected years and assumed depletion levels, the simulation model calculated the impact on season length over the 75 year record. The results are shown in Table III-34 in the preceding section. Under 1970, conditions there are an 88% probability of a full season. By 2000, however, with a depletion level of 2.6 million acre-feet, there is only a 72% probability of a full season and there is a one percent probability of no navigation season at all.

8. Conclusion. Missouri River navigation is totally dependent on releases from the main stem reservoirs. These releases insure both adequate channel dimensions and season length. Without the releases, commercial shipping would not be possible.

Figure IV-C



1977-1978 FLOWS

MISSOURI RIVER FLOWS AT SIOUX CITY, NEBRASKA CITY, AND KANSAS CITY

The main stem reservoirs were constructed primarily for flood control and for off stream consumptive uses in the upper portion of the basin. These consumptive uses are in direct competition with navigation for a limited amount of water. In authorizing documents, upstream consumptive uses are given specific priority over navigation and this is not expected to change. The two major off-stream uses are irrigation and energy development; both of which should experience significant growth over the next 20 years. The result will be less water for navigation and greater probabilities of reduced service.

Possible Corps strategies for coping with this problem are limited. Construction of a series of locks and dams would greatly reduce the amount of water needed for navigation, but this course of action is highly unlikely. Increased coordination between the Corps and shippers could promote the most efficient utilization of what water will be available. Under drought conditions, the Corps and shippers may want to establish procedures for selecting tradeoffs between flow rate and season length. More studies of the river could be used to define minimum flow needs in greater detail and relate those flows to shipping constraints.

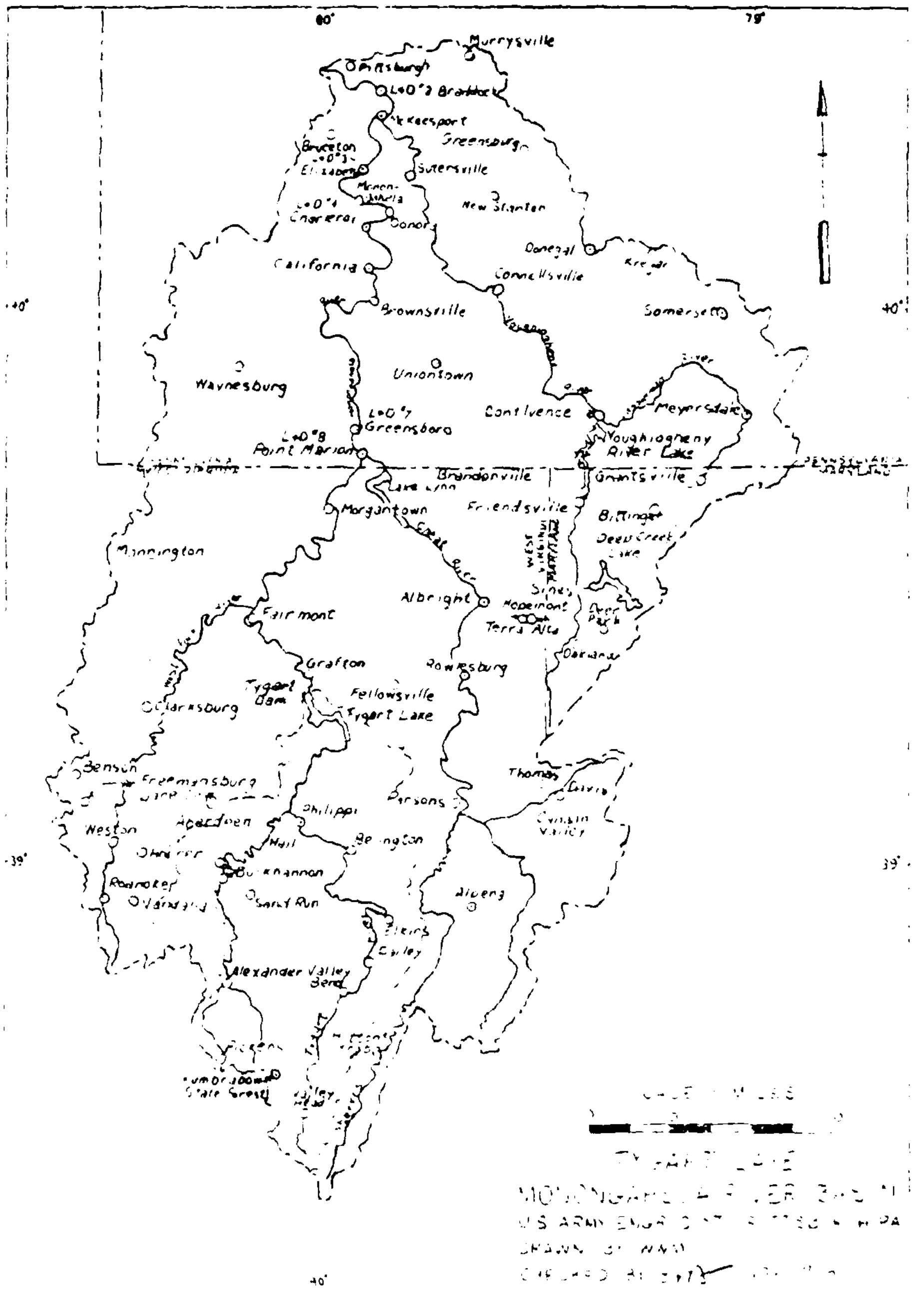
Other responses are not available to the Corps would involve changing the authorizations of the Missouri River projects. Limits on withdrawals could be established or the priority rankings could be changed, but would require an act of Congress. There will certainly be sufficient water for full service navigation, if it is given a high enough priority over other uses.

(c) Monongahela River (Region 7)

1. Topography. The Monongahela and Allegheny are the two rivers which join in Pittsburgh to form the Ohio River. The Monongahela drains 7,386 square miles in southwestern Pennsylvania and northern West Virginia and contains four main tributaries: West Fork, Tygart, Cheat, and Youghiogheny Rivers. Streams in the basin are characterized by narrow, steepsided valleys which are conducive to rapid runoff. The main channels are marked with placid reaches with many meanders, alternating with rough and turbulent reaches. A map of the basin is shown in Figure IV-D.

Figure IV-D

Monongahela River Basin



2. Climate. The climate in the Monongahela basin is temperate and humid with a wide seasonal variation in temperature. Precipitation is well distributed throughout the seasons with a normal annual total of about 45 inches, varying from 36 to 63 inches with higher amounts occurring in the southwestern portion of the watershed. The normal monthly precipitation is highest in June and July with about 4.5 inches and lowest in November with about 3.0 inches.

Average annual snowfall ranges from 38 inches in the lower valley to 107 inches in the higher mountain areas. Snow cover is generally subject to melting throughout the winter season and is frequently a contributing factor to winter and early spring flooding.

The natural discharges of the streams of the Monongahela River basin show a wide seasonal variation. The highest flows generally occur during the months of December through April when soils are already saturated or frozen and most conducive to high runoff. However, it is possible for major floods lasting several days to occur at any time of the year. Most of the floods during the winter/early spring period are the result of heavy, prolonged rainfall over large areas sometimes accompanied by snowmelt. Summer floods generally result from intense thunderstorm rainfall, which may be very local in extent, and which is more likely to occur in the small tributary drainages.

Lower flows occur primarily during the later summer and early fall (August, September, and October) when surface runoff declines. As surface runoff ceases, the entire flow of unregulated streams is drawn from groundwater storage, which generally is already at its lowest levels at this time of year.

3. Reservoirs. There are two federal multipurpose reservoirs in the Monongahela basin: Tygart Lake and Youghiogheny Lake. Youghiogheny Lake provides protection throughout the Youghiogheny basin, recreational opportunities, and flow augmentation to the lower Monongahela River. However, the flows do not benefit navigation above Lock and Dam 3.

Tygart Lake is authorized to provide flood reduction throughout the Monongahela basin and flow augmentation to support navigation. The project was completed for

full operation in 1938 and controls a drainage area of 1184 square miles. There is a maximum of 278,400 acre feet of storage capacity available for flood control for the period of mid-December through mid-March. The reservoir is filled from mid-March through April as water is stored for low flow regulation. By May there are 178,400 acre-feet available for flood control. The remaining usable reservoir capacity of 100,000 acre-feet is available for flow augmentation. Depending upon the weather, this storage is released as necessary to maintain minimum navigation flows in the Monongahela River. By mid-winter the low flow storage has been released and available flood control storage is again at 278,400 acre-feet.

4. Navigation. The Monongahela River project for commercial navigation extends from the mouth upstream for 129 miles. Channel dimensions are maintained by a system of nine locks and dams.

The amount of water needed for navigation is that required for lockage volumes, leakage past locks and dams and make-up evaporation losses. Water requirements were estimated in the GDM for Point Marion Lock which would replace Lock 8, just above the confluence of the Cheat River with the Monongahela River. It was calculated that 3.3 cfs per lockage plus 75 cfs for continuous leakage and evaporation would satisfy commercial navigation through the existing 56 by 320 foot lock with a head of 19 feet.

Since the whole navigable channel is controlled by locks and dams, depth is not generally a problem. However, during extreme low flow conditions (the 1930 drought) the pools have been drained, which completely stopped all navigation. As long as flow remains above the rate of leakage and evaporation some navigation should be possible. Only the number of lockages would be limited by the flow.

In 1974, there were 5,805 lockages through Point Marion Lock. The busiest month of the low flow season was October which accounted for 10 per cent of the annual total or a daily average of 18.7 lockages. The water demand for this traffic level as 137 cfs (62 cfs for lockage plus 75 cfs for leakage).

5. Reservoir Management. The design of and regulation schedule for Tygart Lake were developed primarily

to fulfill the minimum requirement of maintaining navigation along the Monongahela River under the most adverse conditions that might reasonably be expected. Using the historic 1930 drought as a criterion, it was determined that sometimes it might be necessary to maintain a constant discharge of 340 cfs from Tygart Lake for the five and one-half month period period from 1 July to 15 December. The flow, translated into a volume, would be 675 acre-feet per day on 113,400 acre-feet for the 168-day period. The record of the Tygart River during the 1930 drought reveals that although on occasion the discharge from 1 July to 15 December was approximately 13,000 acre-feet. Because the difference between the total volume of required discharge and the minimum expected inflow determines the volume of storage that must be in the reservoir prior to the low flow period, the use of 1930 as a criterion necessitated about 100,000 acre-feet of storage by 1 July.

As part of the operating studies for Tygart Lake a hydrologic model of the reservoir system was developed. The model simulated operation of the reservoir under the existing rules with 38 years of historical steamflow data as an input. The purpose of the model was to verify that under the present operating scheme, the flow in the Monongahela River would not have been less than 340 cfs over the entire period of record.

6. Effects of Reservoir Management on Navigation. Tygart Lake was designed to provide 340 cfs for the five and one-half month dry season during the 1930 drought, which was the drought of record at the time. Simulation of historical flows and actual operating experience indicate that the reservoir could insure a minimum flow of 340 cfs for 100 per cent of the time in the existing 72 year period of record.

Navigation on the Monongahela River in October of 1974 through the Point Marion Lock required an average flow of 137 cfs for 580 lockages. During the worst drought of record, Tygart Lake would have provided enough water to accomplish 2,481 lockages per month, which is more than that capacity of the existing lock.

7. Conclusions. With the present system of locks there is sufficient storage space and water in the

Tygart Reservoir to meet navigation needs for the foreseeable future. Three possible changes could occur which would affect that conclusion.

Construction of a larger lock coupled with a growth in traffic would increase the demand for water. However, projections included in the Grays Landing and Point Marion GDM indicate that there is sufficient water through the year 2020.

Increases in offstream water consumption, if allowed to withdraw from Tygart Lake or the Monongahela, could reduce the water available for navigation. The presence of fossil fuel reserves in the basin could place added pressure on the water resource. Corps personnel have indicated that they are evaluating all withdrawal permits from the Monongahela on a case by case basis in order to avoid this possibility.

Relocation of a storage reserves to uses other than navigation, such as recreation, would also adversely impact low flows. However, recreation pressures on Tygart Lake do not appear to be great and, therefore, this is not expected to occur.

(d) Arkansas-Verdigris River (Region 9)

1. Topography. The Verdigris River navigation system shown in Figure VII-I extends from the Arkansas River upstream for about 50 miles to the Port of Catoosa, Oklahoma. The Verdigris basin has a total area of 8,303 square miles, most of which is undulating plain. The slope of the navigable portion averages 0.8 feet per mile in a well-defined but winding channel.

2. Climate. The Verdigris basin lies in a region characterized by moderate winters and comparatively long, hot summers. Summer rains are usually intense thunderstorms of short duration and limited extent. Winter rains are low intensity but last for several days and cover large areas. Mean annual precipitation in the basin ranges from 32 to 40 inches. The annual maximum is 57 inches and the annual minimum is 23 inches. Approximately 68% of the precipitation occurs between April and September.

3. Reservoirs. There is one reservoir, Oologah, in the basin which has navigation releases as an authorized project purpose. Other project purposes are flood control, water supply, fish and wildlife, hydropower and recreation. Oologah Dam is located near Claremore, Oklahoma at river mile 90 on the Verdigris. (see Figure IV-E). Construction on the Dam was started in 1940 and the first phase of storage began in 1963. The conservation pool for the final phase of development was filled in 1972.

The total storage in the lake is 1.5 million acre feet. Of this amount, 168 thousand acre feet are reserved for navigation use. Maximum yield from this storage is 167 cfs. The remaining storage is allocated with equal priority among the other uses. The 168,000 acre-feet are intended to insure water needed for navigation on the Verdigris River. It is assumed that additional needs on the Arkansas will be made up by tributary inflow.

4. Navigation. Navigation on the Arkansas and Verdigris system is supported by a series of locks and dams which maintain channel dimensions. Water is required for lockages, leakage, and evaporation.

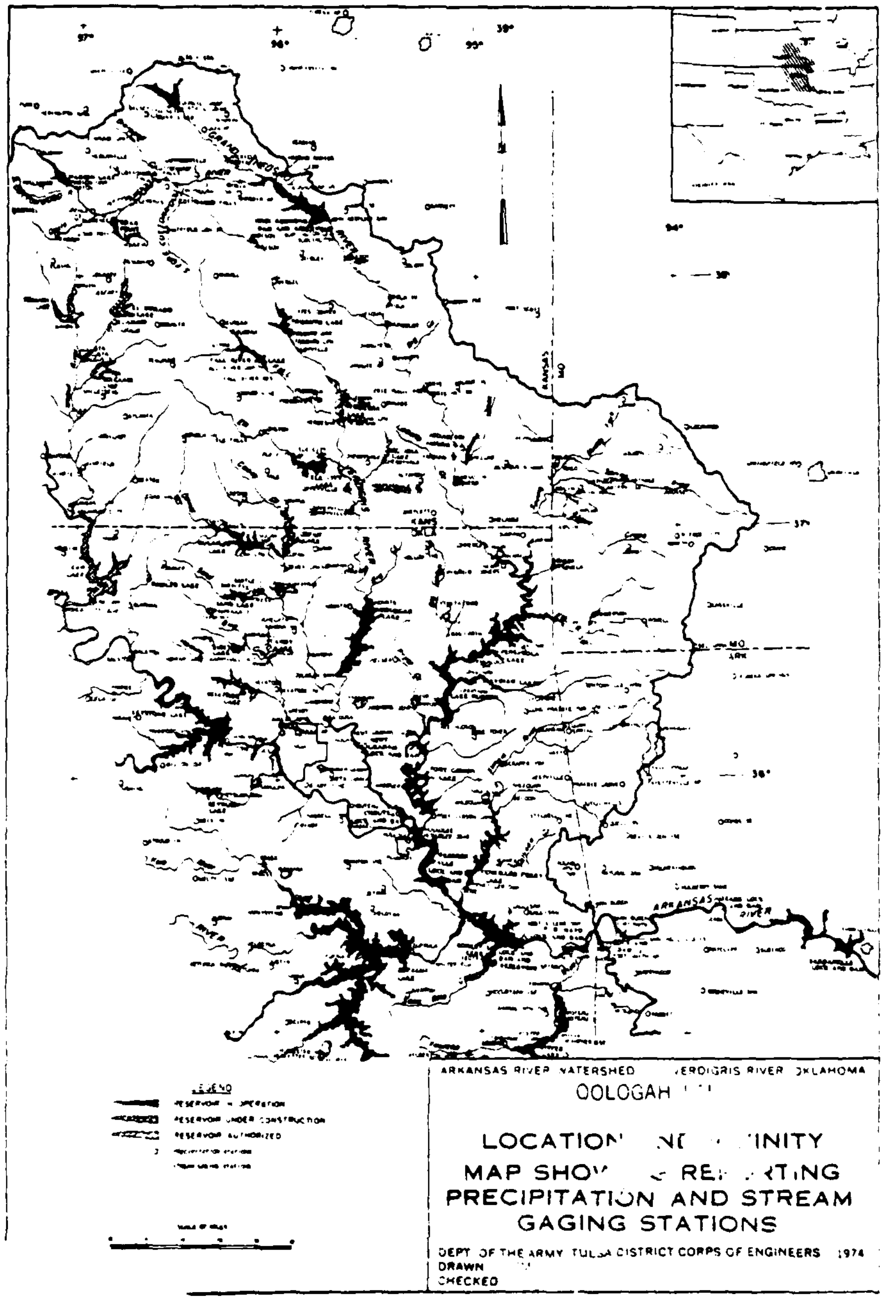
The original estimates for the Verdigris assumed that the design level navigation need for water would be 93 cfs for lockage and 24 cfs for evaporation and leakage. The 168,000 acre-feet of storage could supply that amount (117 cfs) for 724 days.

More recent calculations for the Verdigris have stated that the design level navigation for water is 161 cfs for lockage, 70 cfs for leakage, and 20 cfs for evaporation for a total of 251 cfs. This amount is greater than the yield from the storage in Oologah Reservoir. At the time these estimates were prepared it was assumed that the shortage would be made up by water quality releases from the Caney-Bird reservoir system.

5. Reservoir Management. Oologah Reservoir is operated with 16 other reservoirs as part of the overall Arkansas River basin system. A model simulation of this system is prepared by the Corps using 25 years of historical hydrological data and the present operating procedures. The model calculated inflow, storage, and releases for each reservoir and stream flows at selected control

Figure IV-E

Arkansas-Verdigris Basins



points. Levels of service provided to the various water uses were evaluated.

The model description identified minimum flows for navigation in the Verdigris ranging from 140 cfs to 260 cfs depending on the time of year. The average needed for navigation was 180 cfs. Unfortunately, the simulation results do not reflect this constraint. During drought periods, flow in the Verdigris drops to 115 cfs in the model. This discrepancy remains a question for further study.

6. Effect of Reservoir Management on Navigation. It is difficult to precisely define the effects on navigation resulting from the operation of Oologah Reservoir. Initial calculations estimated the need for navigation at 117 cfs, which was less than the 126 cfs yield from Oologah. More recent estimates place the need for navigation at 251 cfs, which Oologah could not supply.

Simulation results are also confusing. Although navigation needs were set at an average of 180 cfs, the simulated stream flows would always decrease to 115 cfs during a drought.

Evaluation of these results is hindered by the fact that the Arkansas is a relatively new system. There are only about nine years of full system operating experience and there have been no significant droughts during that time. The design traffic levels have not yet been reached and so navigation demands for water have not yet reached their maximum.

7. Conclusions. It is not possible at this time, based on data presently available, to determine whether or not there is a conflict between navigation and other water users on the Verdigris River. Further study will be required to resolve the questions associated with the simulation modeling efforts and the calculations of navigation water demand.

(c) Apalachicola River (Region 11)

1. Topography. The Apalachicola-Chattahoochee Fling (ACF) navigation system covers parts of the states

of Florida, Alabama, and Georgia (see Figure IV-F). The area is a flat coastal plain and drains into the Gulf of Mexico. The basin is relatively narrow for its length and has few minor tributaries.

2. Climate. The ACF system lies in a region of heavy annual rainfall which is fairly well distributed throughout the year. There is some seasonal variation with about 37% of the normal annual precipitation occurring, from December throughout March, while only about 18% falls in the dry period of September through November. Moderate snowfall occurs in the northern portion of the watershed, but it seldom covers the ground for more than a few days at a time and has not been a factor in peak flows.

3. Reservoirs. There is one reservoir in the basin, Buford Dam (Lake Sidney Lanier), which has authorized releases for navigation. Its other purposes are flood control and power generation. The lake is also used for recreation, although that was not one of the original authorized purposes.

Buford Dam is located on the Chattahoochee River in Georgia about 35 miles northeast of Atlanta. It has a drainage area of 1,040 square miles and a total storage capacity of 2.55 million acre-feet. Storage for power and low flow augmentation is 1.05 million acre-feet contained between elevations 1,035 and 1,070. Exclusive flood control storage of 0.64 million acre-feet is maintained between elevations 1,070 and 1,085.

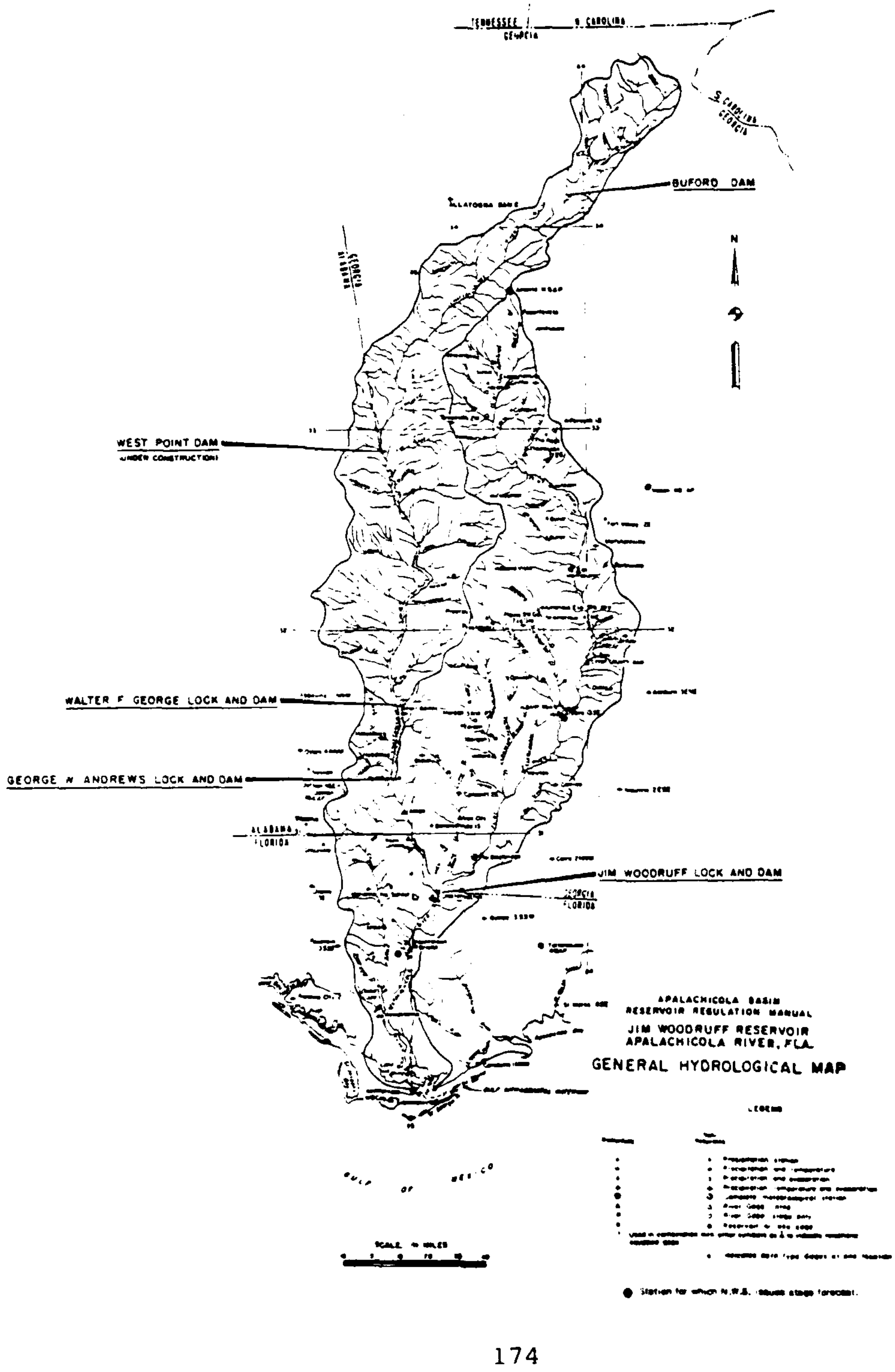
During the summer an extra foot of storage is taken away from flood control and added to the navigation storage.

4. Navigation. Navigation on the ACF extends upstream from the Gulf of Mexico to Bainbridge on the Flint River and Columbus on the Chattahoochee River. Above Jim Woodruff Lock and Dam channel dimensions are maintained by the pools behind a series of locks and dams. From Jim Woodruff Lock and Dam to the Gulf of Mexico the Apalachicola River is free flowing for 108 miles and requires from about 13,000 to 17,000 cfs to insure a nine foot depth. As flows decrease below this level barge drafts must be reduced accordingly.

The need for supplemental flows is demonstrated by flow probability data for the Apalachicola. During

Figure IV-F

Apalachicola Basin



February, there is a 90% probability that flows will exceed 17,000 cfs drops to only 20%.

5. Reservoir Management. During low flow periods flow augmentation in the Apalachicola River is provided by the releases from Buford Dam. If at all possible, this augmentation is supplied by the scheduled power releases. When more water is needed consideration must be given to the tradeoffs between power and navigation.

Experience has shown that the time of travel of releases from Buford to Jim Woodruff is about six days during low flow periods. This delay makes it even more difficult to plan operations at Buford. However, Jim Woodruff has an allowable drawdown of one foot for pondage, which amounts to 36,000 acre-feet of usable storage. If necessary, water can be borrowed from this storage to supplement natural flows below Jim Woodruff prior to the arrival of water from Buford. This affords some leeway in planning the releases from Buford and permits them to be integrated into the regular power commitments. The effects of temporary releases from Jim Woodruff upon depth in the Apalachicola are shown in Table IV-8.

Table IV-8

Impact on Depth of Temporary Releases from Jim Woodruff

Increase in Release (cfs)	Duration of Increased Release (hours)			
	6	12	18	24
	Estimated Increase in Blountstown Stage (feet)			
2,000	0.40	0.65	1.10	1.10
3,000	0.40	0.65	1.15	1.15
4,000	0.40	0.70	1.20	1.60
5,000	0.50	0.85	1.60	2.00

6. Effect of Reservoir Management on Navigation. The management of long-term drought problems is difficult and these situations are usually handled on a case by case basis by the Corps. An example of the analyses and decisions made during drought conditions is provided as the best available description of the operating system.

In the fall of 1978, the ACF basin experienced below seasonal rainfall causing predictions that channel depth below Woodruff Dam would be 6.5 to 7.0 feet unless releases were made from Buford Dam. The authorized depth of the ACF is nine feet but the channel is often operated at an eight foot depth during the fall low flow periods. Forecasted deficits of stream flow determined the critical period to be of seven weeks duration. In order to help facilitate the decision regarding Buford releases, Corps economists were requested to determine the costs to navigation, hydropower, and recreation if channel depths were reduced from eight feet to seven feet. It should be noted that although recreation is not an authorized purpose at Buford it is so considered as a result of an administrative decision by the Division Engineer.

The added costs to navigation from light loading were calculated to be $234,000 for the seven week period. It was considered probable that shippers would use the light loading option rather than diverting their traffic to overland routing for this short time period.

The impact on hydropower from the drawdown of the Buford pool was calculated to be the loss of three megawatts in plant capability or $234 per day in revenue losses. This totals $11,466 for the seven week period. However, it was indicated that the long range effects would include the possible inability to meet contract commitments. The contract requires the Corps to purchase energy for the utility company if there is a loss in generating capacity.

The costs to recreation were considered negligible for the seven week off-season period. However, costs for maintaining navigation over an extended drought period, which would result in lowered water level at Buford reservoir during the summer of 1979, were calculated to be $4.3 million for recreation benefits lost. This included loss of rental income from commercial marinas and club leases plus loss of visitor recreation days which, at $1.88 per visitor day, totaled $3.1 million. Calculations of idle imvestments for both commercial and private docks totaled $12.1 million.

After weighing the relative merits of costs to navigation, hydropower, and recreation interests it was decided that navigation should be maintained although at a reduced level of service. In effect, the short-term costs

to navigation from reduced flows were found to be higher than to hydropower and recreation. The implications of a long-term reduced flow under drought conditions suggested that hydropower and recreation would be given equal consideration with navigation and that the decision would be determined largely by economic considerations.

7. Conclusions. Problems of low flow and reduced depth are relatively common on the ACF navigation system. Although normally a nine-foot project it is operated with a depth of eight feet during the fall. These problems are mitigated somewhat by releases from Buford Dam. However, the releases which can be made from Buford to aid navigation are constrained by power and recreation demands. Of the two conflicting uses only power is contained in the original project authorization.

As other energy forms become scarcer and more expensive it is likely that tradeoffs between competing uses will increasingly favor power at the expense of navigation.

Two different strategies are possible responses to this problem. The first involves the calculation of benefits from Buford Dam. If recreation, which is not an authorized project purpose, is removed, this may shift the results more in favor of commercial navigation. This approach, however, would be both improbable and expensive in view of the investment in recreation along the shores of the reservoir.

The second strategy involves increased dredging in the lower Apalachicola River. Dredging in this area has been prohibited by Florida state environmental regulations. These restrictions must be considered a significant factor in reducing channel depths. Under present conditions where states set environmental standards for dredging and dredge material disposal these changes may not be possible.

ANALYSIS OF INSTREAM FLOW

Five segments were selected for potential conflicts between navigation and hydropower, flood controls or fish and wildlife release requirements. These segments were: the Missouri (Region 6), the Cumberland (Region 7), the

Arkansas (Region 9), the Alabama-Coosa (Region 12), and the Columbia (Region 18). Each of these segments was examined for the effects of flood control and hydropower releases on water availability for navigation. In addition all waterways segments were surveyed for required releases for water quality maintenance or fish and wildlife support. A summary of the results is presented below.

(a) Fish and Wildlife or Water Quality

1. Effects on Instream Flow. Minimum instream flows of a legal or regulatory nature that have been established for fish and wildlife enhancement or water quality maintenance were identified in this study. Minimum flows for fish and wildlife purposes are usually determined by the physical species of concern. Important physical parameters in the stream environment include velocity, depth, channel width and configuration, and stream bed gradient and substrate. The general effect of flow changes is to alter those properties which affect the inhabitants of the stream. Needs of a species also can change in relation to specific activities and its position in its life cycle. Fish may prefer different conditions for feeding and for spawning, and the larval stage of an organism may require a very different environment than the adult stage. In addition many of these requirements will vary seasonally.

As a result of all of these complicating factors it is usually very difficult to determine specific stream flow requirements. The efforts that have been completed to date are for specific rivers. No general techniques have been developed that may be applied to any free flowing aquatic environment.

Minimum flows for maintaining water quality are most often related to the stream pollutant loading and require a certain volume of water for dilution purposes. These standards are established either to limit the maximum concentration of a pollutant (nitrogen, phosphorus, fecal coliforms) or to insure that a minimum dissolved oxygen concentration is met. The desired dissolved oxygen and pollutant levels will change depending upon the intended uses (drinking, body contact, and fishing) for the

body of water. Minimum flows for water quality requirements are generally constant throughout the year. They may be reduced during the winter months to take advantage of reduced biochemical oxygen demand and increased dissolved oxygen concentrations which occur in colder water.

2. Relation to Navigation Requirements. Minimum instream flows for fish and wildlife of water quality are usually complementary with navigation needs. In places where fish and wildlife requirements have been estimated they always exceed navigation requirements. The only potential conflict arises where navigation is limited on a seasonal basis by factors such as ice. In these cases reservoir releases which are made during the winter for environmental objectives, use water which may be saved to support navigation in the summer if it is needed and if storage space is available.

3. Instream Segment Flows. There are no segment-wide legal minimum flow requirements for either fish and wildlife protection or water quality maintenance. One segment combination, the Columbia River-Snake Waterway/ Willamette River (Segments 51 and 52) has at two locations required releases or instream flows for fisheries purposes. Priest Rapids Dam is required by the terms of its license to release a minimum of 36,000 cfs. The Idaho Power Company Dam at Hell's Canyon also has a minimum flow requirement which varies seasonally. The Columbia River Fisheries Council has developed a complete set of recommended minimum flows for the waterway, but they have not been formally adopted and thus serve only as guidelines.

With respect to water quality maintenance, there are projected specific minimum releases or instream flow minima in four segments. Most extensive are those on the Willamette River (Segement 52) where a system of reservoirs is required to provide low flow augmentation to meet flow objectives at Salem, Oregon, the head of commercial navigation. On the Cumberland River (Segment 21) the Corps has told the state of Tennessee to assume that 1000 cfs will be available at Nashville for permitting and wasteland allocations. On the Alabama and Coosa Rivers (Segment 36) there is a requirement to maintain 240 cfs below Carter's Dam. There is also an agreement between the Corps and Alabama of a minimum flow of 6500 cfs below Claiborne Lock and Dam. Finally, the Apalachicola-Chattahoochee-Flint Waterway (Segment 38) has a minimum flow requirement of 650 cfs at the Vinnings gage.

4. Future Effects. The Instream Flow Service Center in Fort Collins, Colorado is a multi-agency, multidisciplinary group which is developing methodology, guidelines and a data base for use in calculating instream flow requirements. Its programs have been underway for three years. Significant outputs should be available in 1980.

United States Fish and Wildlife Service has recently established the Water Resources Analysis Group at Harper's Ferry, West Virginia. Its mission is to ensure that fish and wildlife resources are given adequate consideration in water and land resource planning and decision making.

In conjunction with these activities, instream flow requirements are receiving a great deal of study in many river basins and geographic regions throughout the nation in response to public awareness of the values of fish and wildlife and other water-related resources. The impact of these programs on instream flows is very dependent upon the level of public interest and support which they receive. In most states with "western water law," instream flows are not normally considered a beneficial use. These states may require legislative changes or court rulings before environmental instream flows will have any legal standing. In addition, agricultural and energy interests will provide increasing competition with environmental concerns for use of a limited resource. It seems unlikely, therefore, that any new instream flow requirements for fish and wildlife will be established in locations in western states where they would significantly impact commercially navigable waterways.

In states with riparian law there is a greater possibility of establishing minimum instream flows for fish and wildlife since these states have a traditional interest in maintaining stream flows for the use of downstream land owners. Also, since these states are generally not as water deficient as the western states, there is more of a tendency to be generous with the resource and commit flows to areas outside of conventional economic concerns. The impact upon commercial navigation of these commitments will most likely be indirect. The majority of effort on environmental instream flows will probably be centered on smaller non-navigable streams if only because they comprise many more river miles than navigable streams. However, nearly all of these streams

are tributary to navigable waterways. Instream flow requirements in tributary streams will eventually contribute to the navigable rivers and the sum of a set of tributary instream flows would establish an effective minimum flow in the main river.

(b) Hydropower

1. Effect on Instream Flow. Hydropower plants generate electricity by utilizing the potential energy available in a river as it falls from high elevations to lower elevations. The generating facilities are usually associated with either a run of the river facility or a storage facility. Run of the river plants have no impact on navigation since they do not modify the volume or the timing of stream flows. They generate electricity in direct proportion to instantaneous stream flow.

Storage facilities do not change the long term stream flow volume but have the capability to retain water during periods of low energy demand and release it through turbines in periods of high demand. This control of output gives hydropower storage projects a flexibility which is unmatched in any other form of electrical generation. Most processes now in use for generating electricity have a relatively constant output. It is difficult and time consuming to shut down or start up a nuclear or fossil fuel power plant. Thermal power plants are therefore normally used to satisfy base or constant demand and hydropower plants are frequently used for load matching or meeting peak demands. Pump storage projects in conjunction with hydropower operation in the future will tend to increase water releases in peak periods.

2. Relation to Navigation Requirements. The primary interaction between hydropower and navigation relates to the timing of releases from hydropower storage facilities. Dams operated for maximum hydropower benefits will schedule all of their releases during peak electrical demand periods and make no releases during offpeak hours.

These wide variations in flow rates can cause several problems for navigation interests. When the turbines are shut off, flow in open channels can drop low enough to reduce channel depth below authorized dimensions. During maximum peak generating periods flows can be high enough to make it difficult to maneuver large or

underpowered tows. However, what seems to be the most prevalent problem occurs during the transition from low to high releases. If this transition is made too quickly it creates a "wave" which cannot be surmounted by smaller towboats. This wave can also catch towboat operators by surprise as the river abruptly changes from low to high velocity regime, which can precipitate accidents. In segments where this phenomenon is severe or frequent, tow operators usually tie off to the shore until the velocity stabilizes. This leads to longer travel times.

Most hydropower releases, however, are not made independent of releases for other project purposes. In typical Corps multi-purpose reservoirs, releases for other objectives, such as water quality or navigation, are made through the turbines so that hydroelectric commitments are met at the same time that other instream water uses are satisfied. The only difficulties in this procedure arise where the timing of the different water uses does not agree. In some segments there are minimum weekly average flow requirements for navigation. These requirements are often fulfilled by hydropower releases during the five weekdays. By Sunday the channel can be less than authorized depth even though the necessary releases have been made for the week.

Instream flows resulting from hydropower commitments are difficult to specify because they are very dependent on the available water and the other tradeoffs which can be made in each case. Reservoir releases were examined for hydropower purposes on five waterway segments with significant hydropower and flood control effects on navigating: Upper Columbia-Snake Rivers; Alabama-Coosa Rivers; Cumberland River; Missouri River; and Arkansas-Verdigris Rivers.

<u>3. Columbia-Snake Instream Flows (Region 18).</u> Navigation on the Columbia-Snake Waterway requires only the small amount of water for lockages since the system is tidal or canalized for its entire length. This amount of water is easily supplied by complimentary hydropower releases. A schedule for typical wet and dry years is shown in Figure IV-G and IV-H.

Releases for hydropower, however, do have some negative effects on navigation. During the low flow months of November through March, which also correspond to a high power demand period, peaking schedules do require

Figure IV-G

Columbia River High Flow

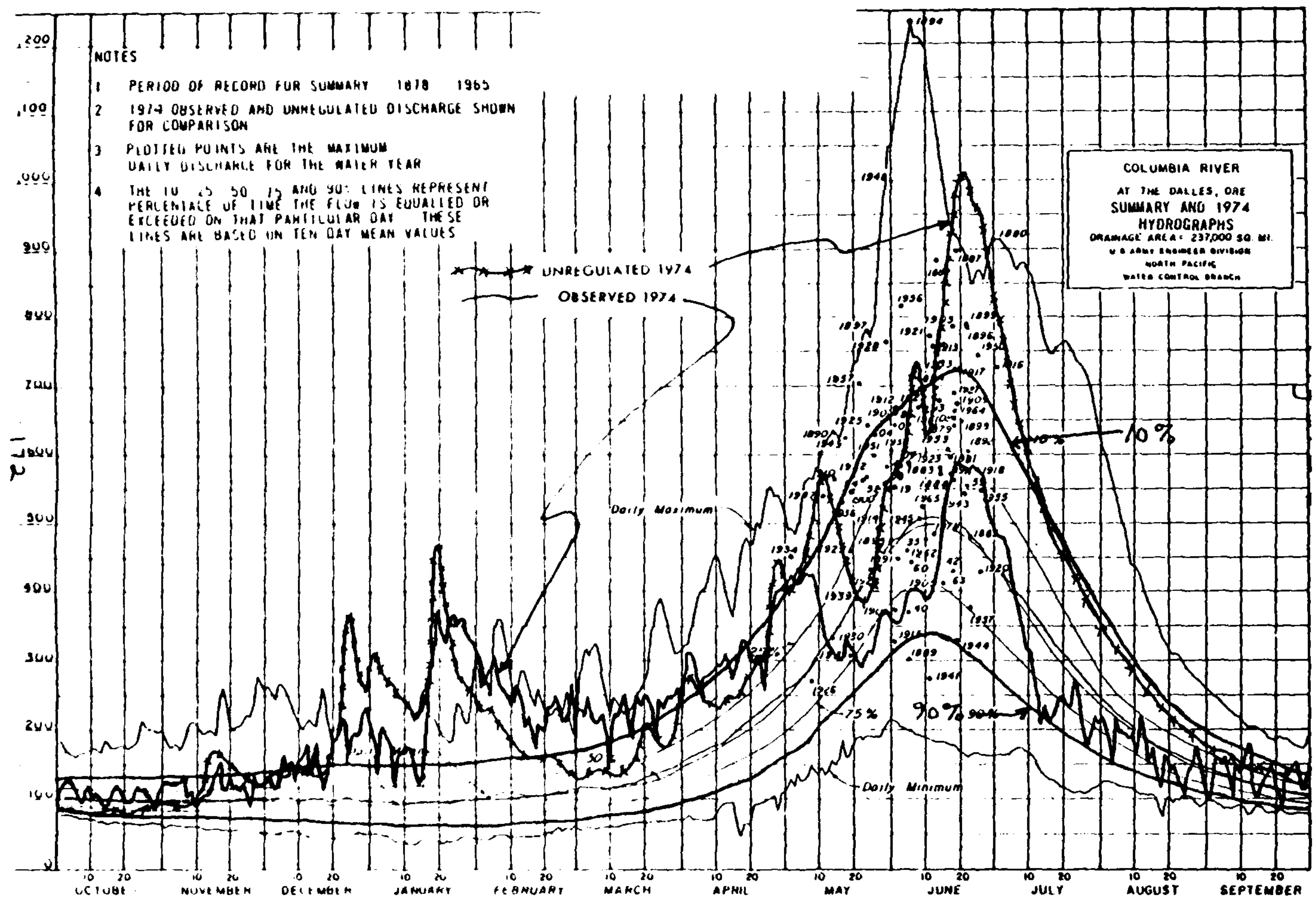
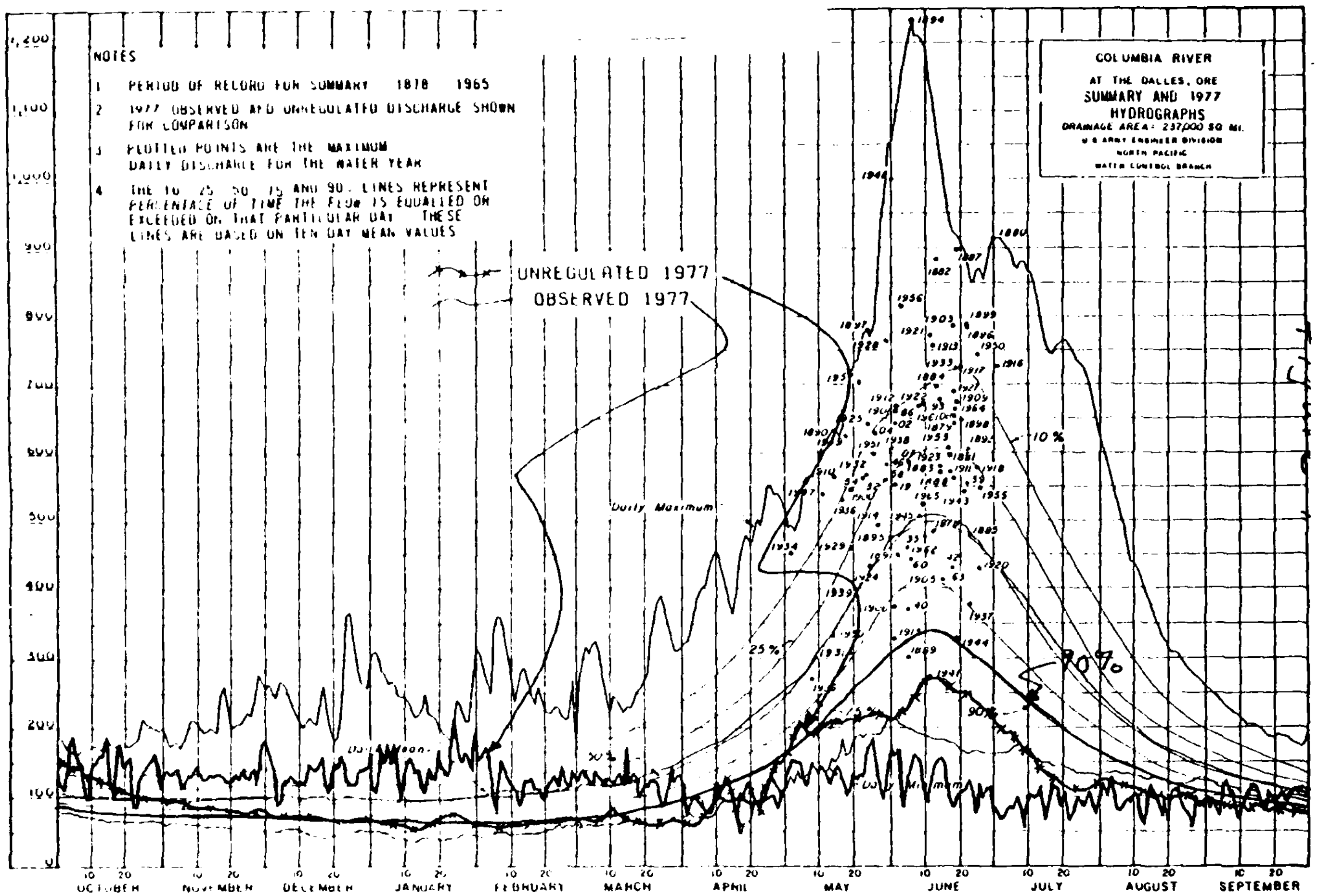


Figure IV-H

Columbia River Low Flow



barge operators to make certain adjustments. Depth constraints resulting from rapid drawdown behind peaking stations occur in the McNary and Ice Harbor pools. (See map in Figure IV-I) These pools can be reduced right to their authorized 14 foot depth, which is a problem to most barges that are loaded to 13 to 14 foot depths. Delays up to six hours may occur but in practice barge companies try to maintain radio contact with the lock master in order to most efficiently schedule their passage during high water periods.

Tow operators must also be aware of problems which can be caused by high velocities around downstream approaches to locks and rapid fluctuations of water levels. There have been instances of barges breaking free from stationary tie offs when emergency start ups or shut downs of turbines have changed downstream stages unexpectedly.

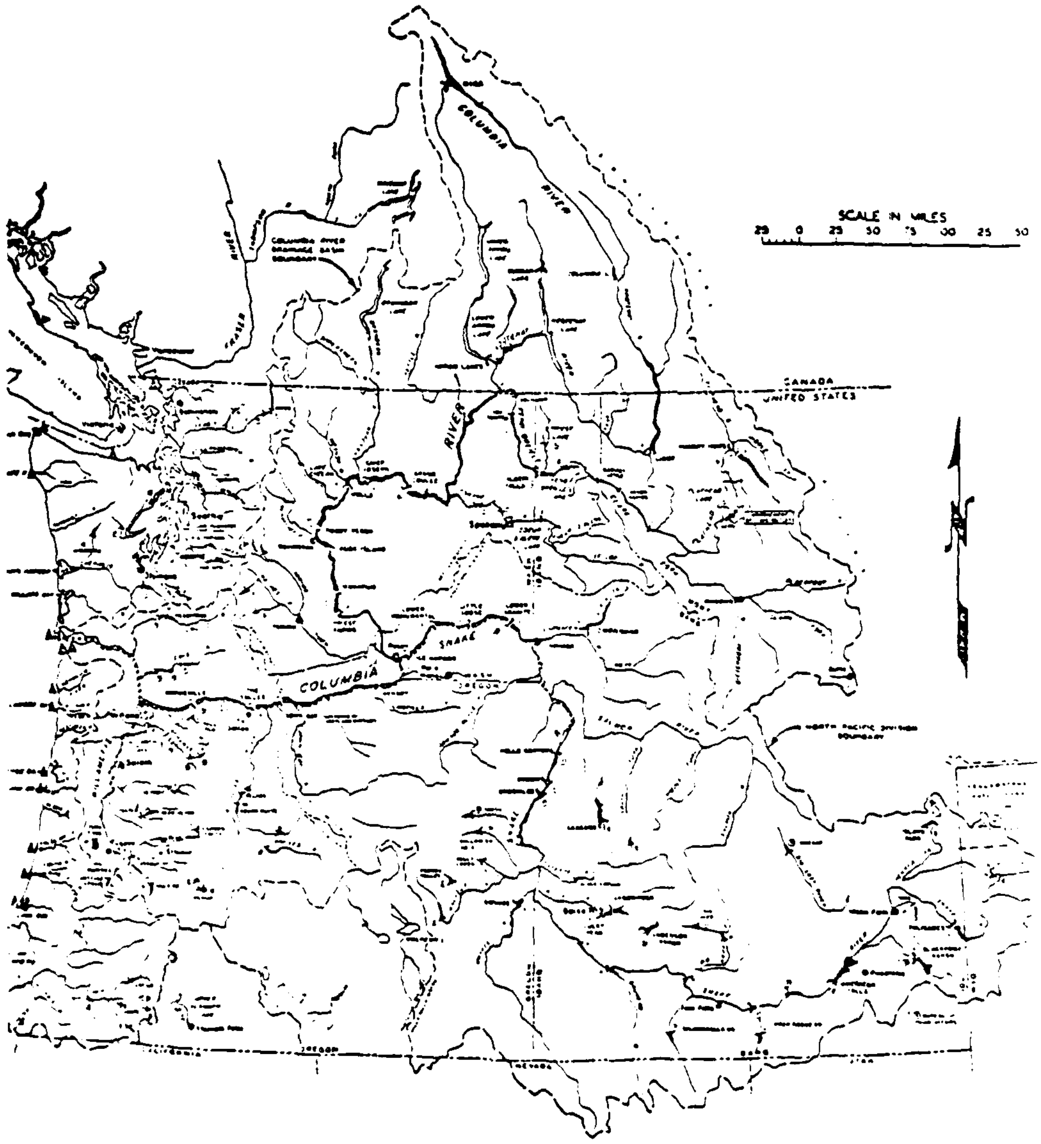
4. Alabama-Coosa Instream Flows (Region 12). The Alabama-Coosa Waterway (see Figure IV-J) has three locks and dams on the navigable portion and two headwaters dams, which are all owned by the Corps. In addition, the Alabama Power Company (APC) owns five upstream dams on the Coosa and Tallapoosa Rivers. Actual releases from the Corps-owned Millers Ferry LOck and Dam for 1977 through 1979 are shown in Figures IV-K and IV-L.

Releases for hydropower operations have a significant effect upon navigation on the Alabama River. The APC has a working agreement with the Corps for the operation of their five hydropower projects. The agreement stipulates that a minimum of 32,400 day-sec.-fe. will be released from APC reservoirs over a seven-day period. In order to meet peaking load requirements during the low flow season the APC will often release the entire amount over the five-day working week and practically zero over the weekend. Occasionally single day releases may constitute up to one third of the total weekly requirement. The generating units of the APC are all remote controlled and are automated to function according to load requirement. Therefore, even the APC is not aware of the precise scheduling of their releases on an hourly basis.

5. Cumberland River Instream Flows (Region 7). Navigation on the Cumberland River is supported by a series of locks and dams which all have hydropower capacities. Operation of the Cumberland River system is also closely related to the Tennessee River (see map in Figure IV-M).

Figure IV-I

Columbia River Basin



LEGEND

RESERVOIRS EXISTING OR UNDER CONSTRUCTION

Ⓐ CORPS OF ENGINEERS

Ⓑ BUREAU OF RECLAMATION

Ⓟ NON-FEDERAL

▲ CORPS OF ENGINEERS HARBOR PROJECTS

•••••• CORPS OF ENGINEERS RIVER CHANNEL PROJECTS

Figure IV-J

Alabama-Coosa Basin

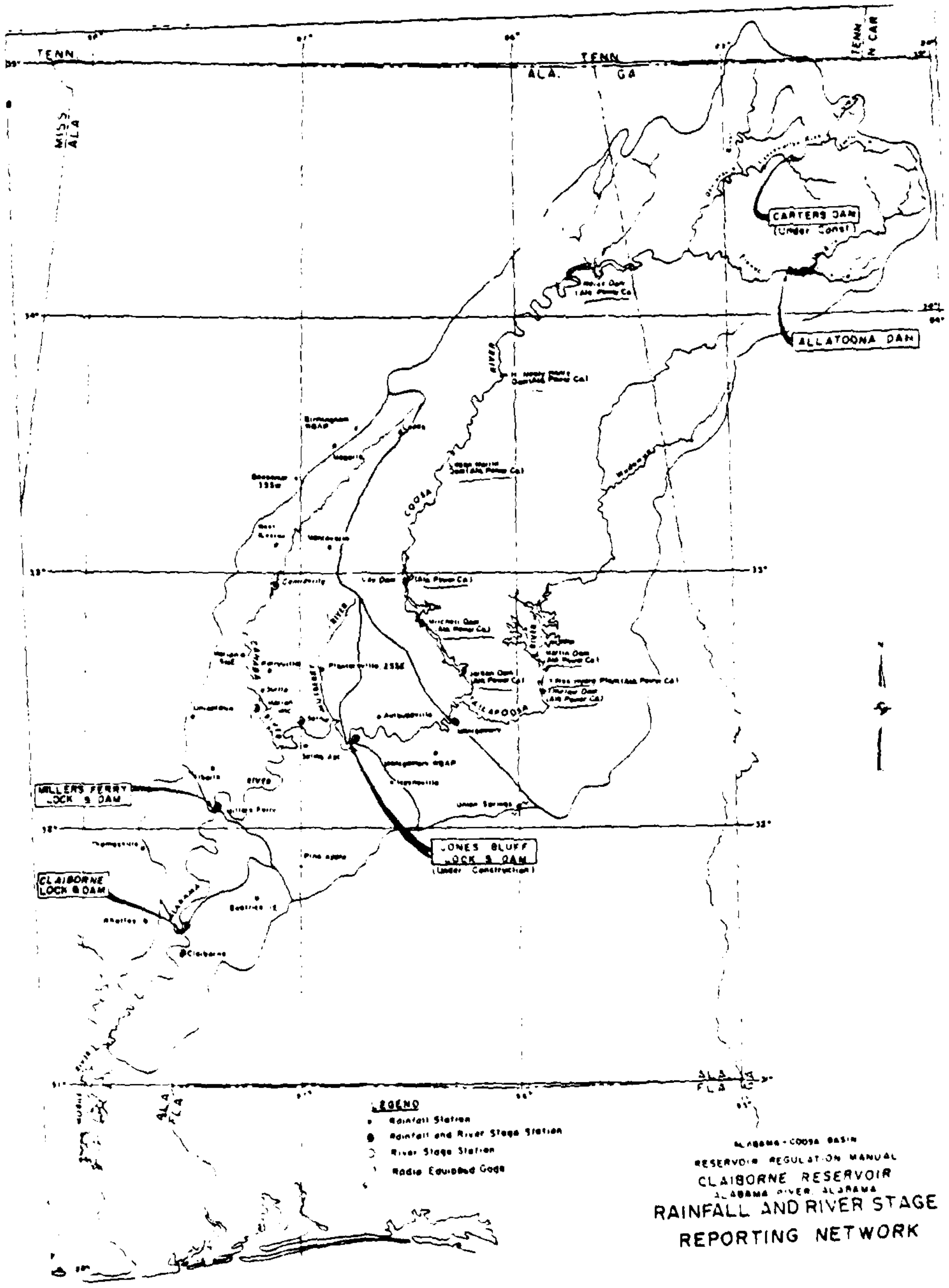


Figure IV-K

Alabama-Coosa - Low Flow

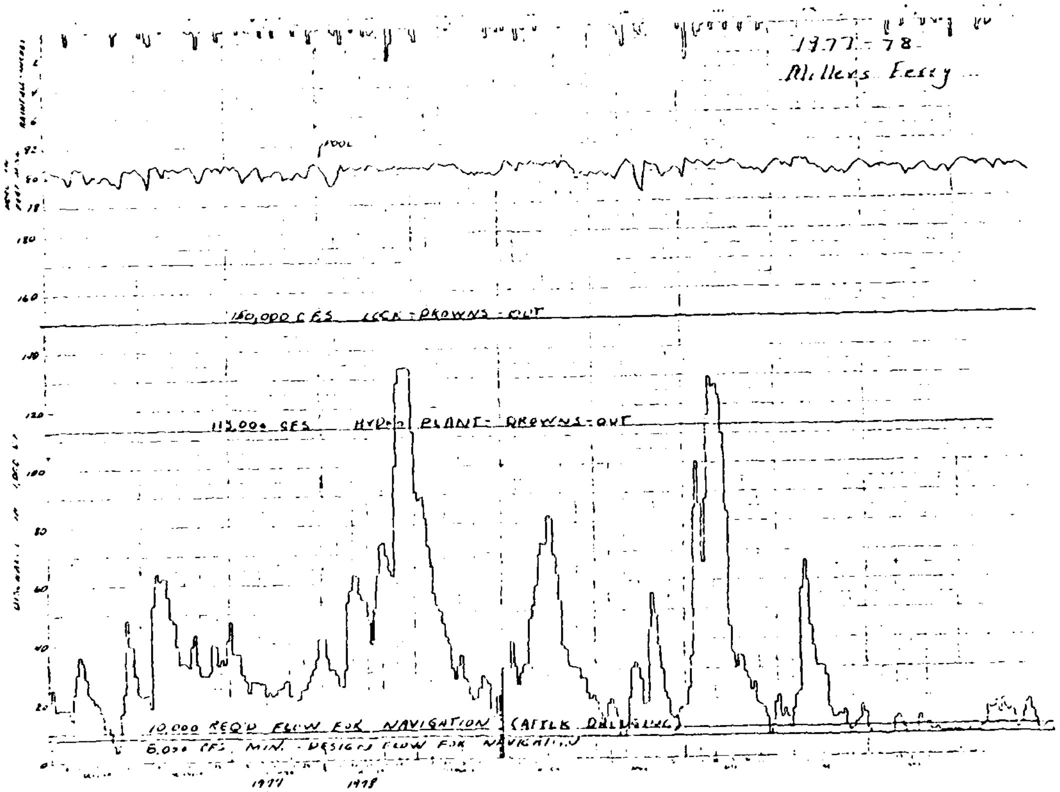


Figure IV-L

Alabama-Coosa - High Flow

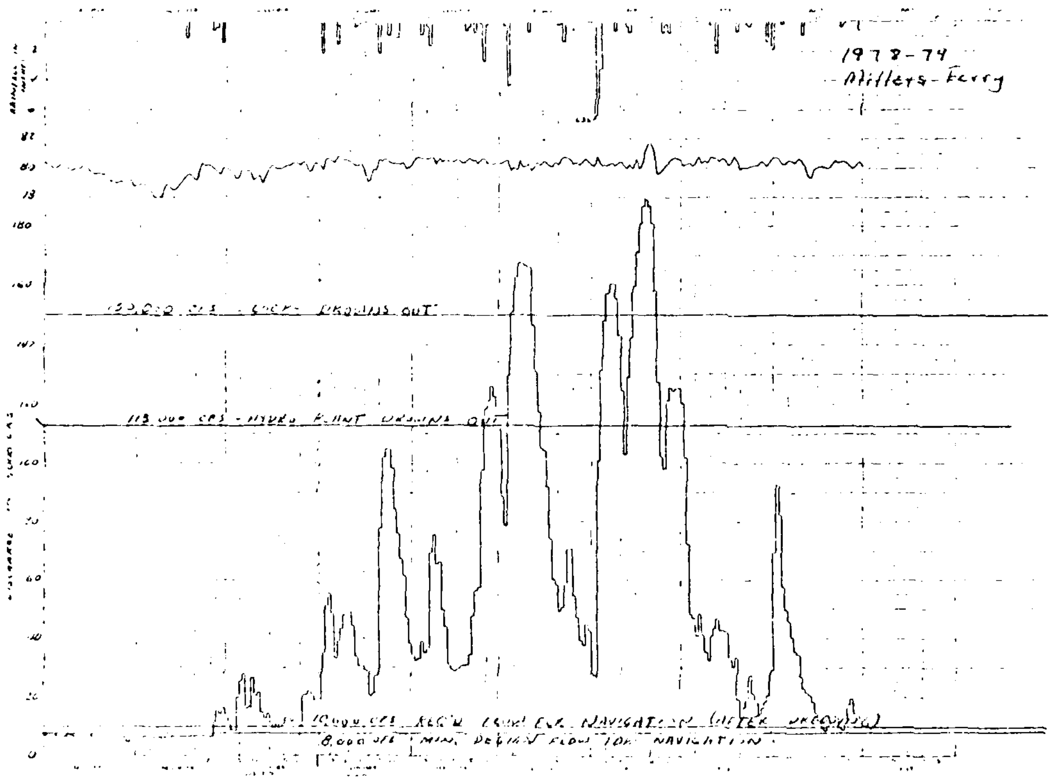


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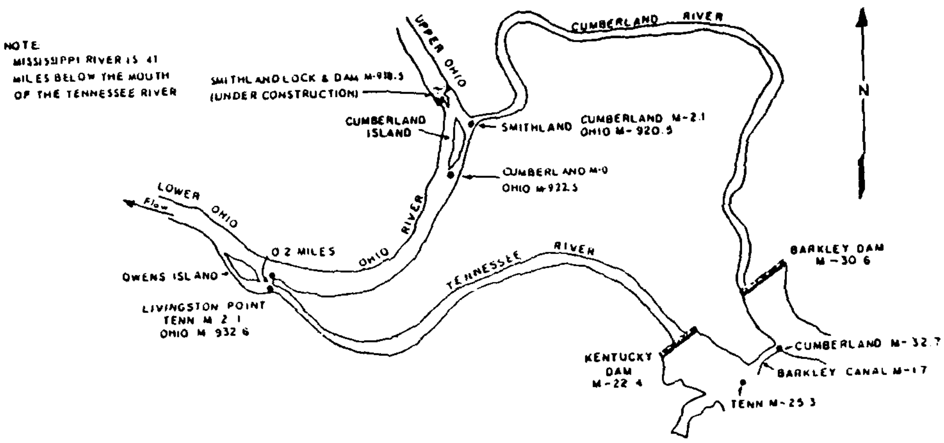
Figure IV-M

Cumberland and Tennessee Rivers



Barkley Lock and Dam, the lowest on the Cumberland River is located 31 miles upstream from its confluence with the Ohio River. The Tennessee Valley Authority's Kentucky Lock and Dam is located adjacent to the Barkley project, on the Tennessee River, 22 miles upstream from its confluence with the Ohio River. A few miles upstream of the dam, the pools for these two projects are connected by a 1.5 mile long open navigation channel that provides for the interchange of navigation and water between the two rivers.

The TVA schedule for operation of the Barkley project is coordinated with that for the Kentucky plant. The joint approach is designed to maximize power benefits with consideration, given to the effect of stream flow regulation upon bank erosion, navigation conditions, pollution problems, and fish and wildlife. Hydrographs from Barkley Lock and Dam on the Cumberland River, Kentucky Lock and Dam on the Cumberland River, and Kentucky Lock and Dam on the Tennessee River are included as Figures IV-N through IV-Q.

Under normal conditions, the Barkley and Kentucky plants are operated as much as possible in response to electrical demands. Due to control limitations at Dam 52 on the Ohio River, each plant must release a minimum discharge to insure that downstream channel dimensions are maintained. After minimum discharge requirements are met, the capacity of the two plants is scheduled for peak hour use on an efficiency basis. This procedure normally begins loading Kentucky first. As load and flow conditions permit, Barkley is scheduled to increase generation at a maximum rate of one unit per hour. The limitation on the start up of Barkley was established for navigation in order to control velocity changes in the downstream channel.

There are two specific problem areas on the Cumberland that occur because of peaking schedules. Below Barkley Lock and Dam that lack of a steady flow in a narrow and difficult channel is a real hindrance to navigation. The condition is most adverse within six miles below the lock because of three severe bends in the river. Tows which have attempted to navigate these bends experience extreme lateral flows and frequently land on the opposite riverbank. As a result most traffic with an origin or destination on the upper Cumberland River will

Figure IV-N

Cumberland River Low Flow

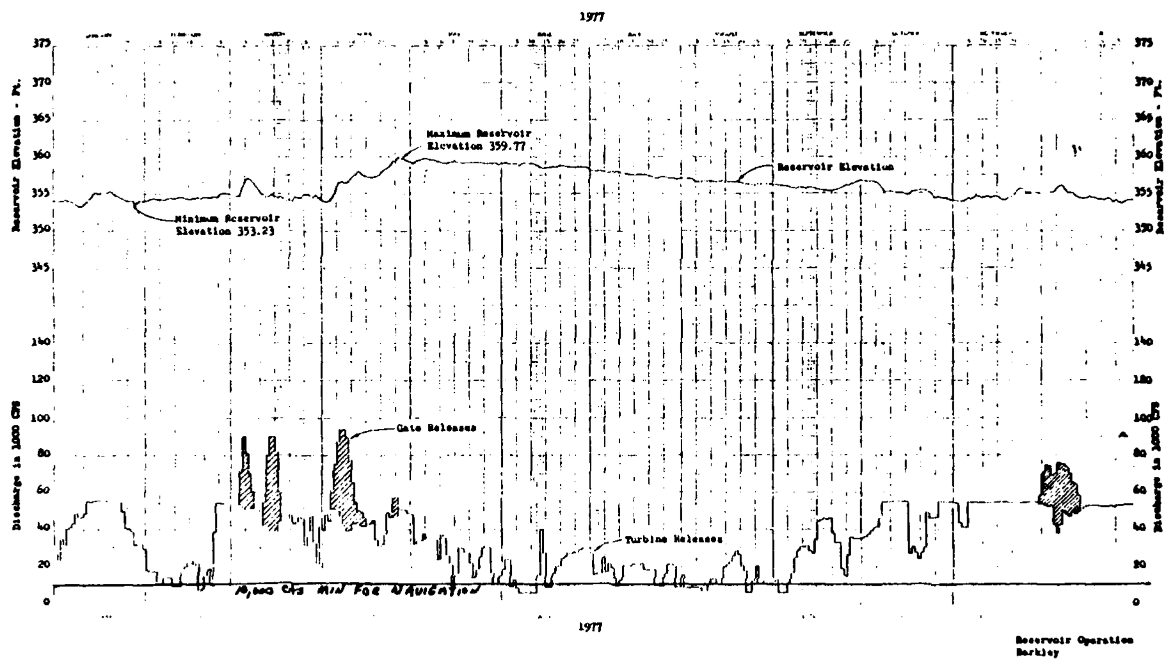


Figure IV-O

Cumberland River High Flow

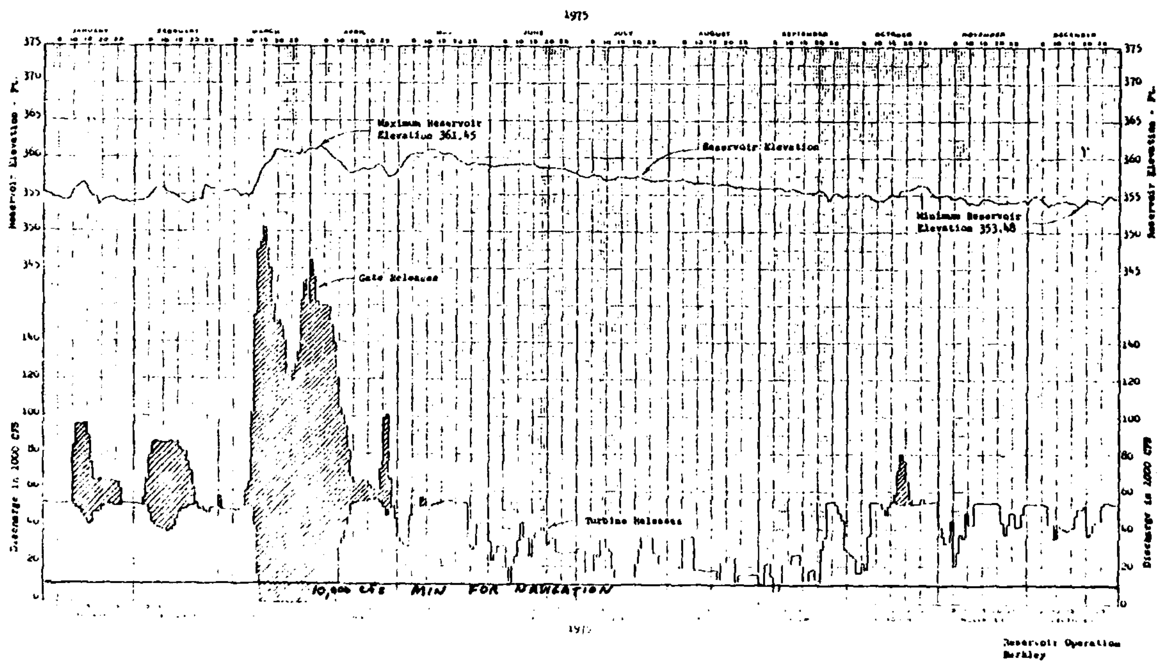


Figure IV-P

Tennessee River Low Flow

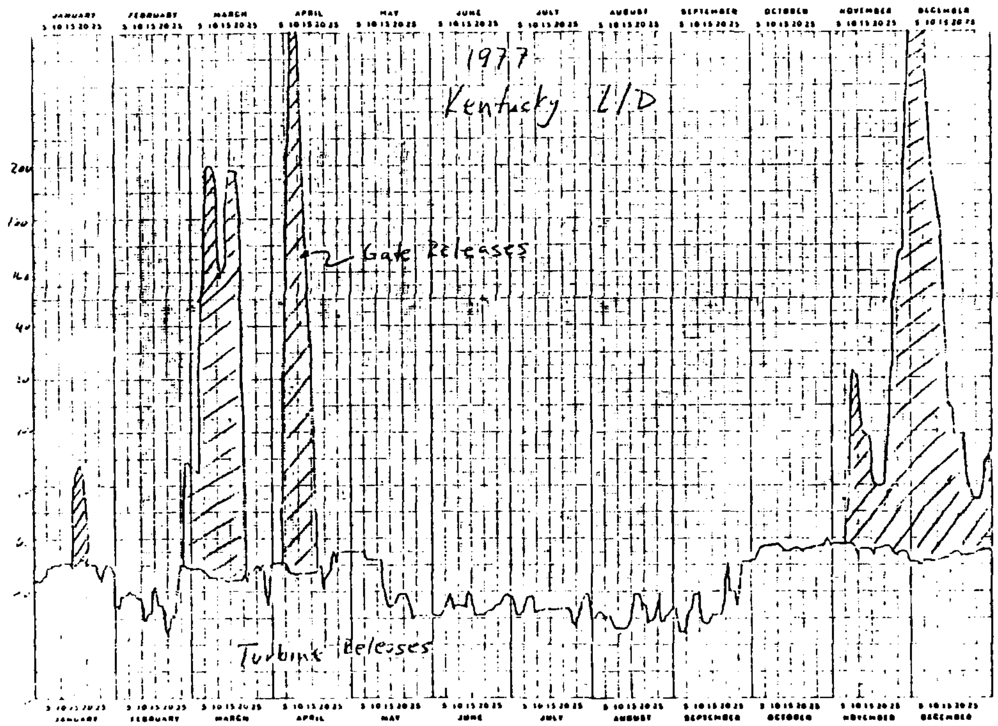
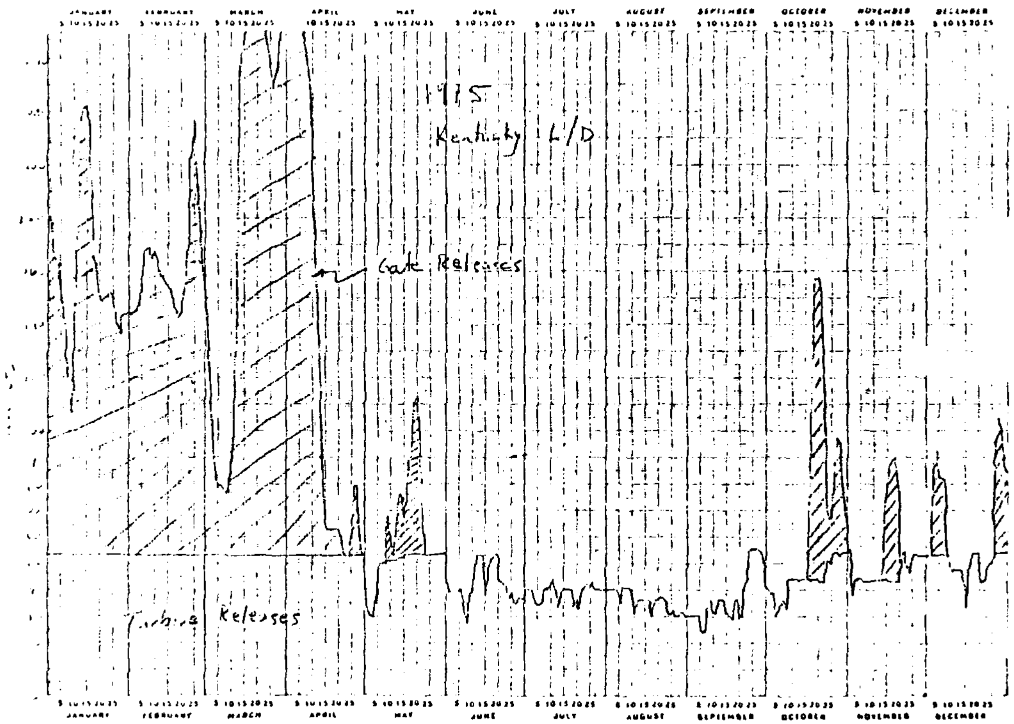


Figure IV-Q

Tennessee River High Flow



use the canal between the two pools and go through Kentucky Lock on the Tennessee River to get to or from the Ohio River.

The other problem spot is below old Hickory Lock and Dam. (see Figure IV-R) Sudden changes in stage resulting from peaking operations have caused tows to break their tie off lines at Nashville Harbor. As a rule of thumb, therefore, operation of the Old Hickory powerplant is constrained so that the maximum change in stage at the Nashville Harbor is three feet within a six hour period at night.

6. Missouri River (Region 6). The navigable stretch of the Missouri River from Sioux City to the Mississippi River is free flowing and so requires ample flow to maintain channel dimensions. (See map in Figure IV-R) Control of the Missouri River above Sioux City is achievd by the six mainstem dams: Ft. Peck, Garrison, Oahe, Big Bend, Ft. Randall, and Gavins Point; all of which have hydropower facilities. Only the lowermost dam, Gavins Point, is responsible for making navigation releases, but since all of the dams are operated as an integrated system they all impact navigation to a degree.

During the navigation season, when downstream flow requirements are high, large amounts of water are released from Gavins Point. This requires that each of the next three upstream reservoirs (Ft. Randall, Big Bend, and Oahe) make released of an equally high magnitude. Oahe reservoir is large enough to support high releases for extended periods with correspondingly high inflows. High summer releases from Gavins Point, Ft. Randall, Big Bend, and Oahe mean high generation rates at these plants. To avoid generating more power than can be efficiently marketed, releases at Garrison and Ft. Peck are held low. When the navigation season ends, the process is reversed and the two upper reservoirs generate most of the electricity while the lower reservoirs cut back. Because the reservoirs are in series it is possible to utilize the upper projects exclusively for peaking and then use Gavins Point to smooth out the flow so that it is suitable for navigation.

A hydrograph of releases from Gavins Point for 1977 and 1978 is shown in Figure IV-S. There is little yearly variation in low and normal flows just below Gavins Point through the navigation season from March to November

Figure IV-R

Cumberland River Basin, Old Hickory Lock and Dam

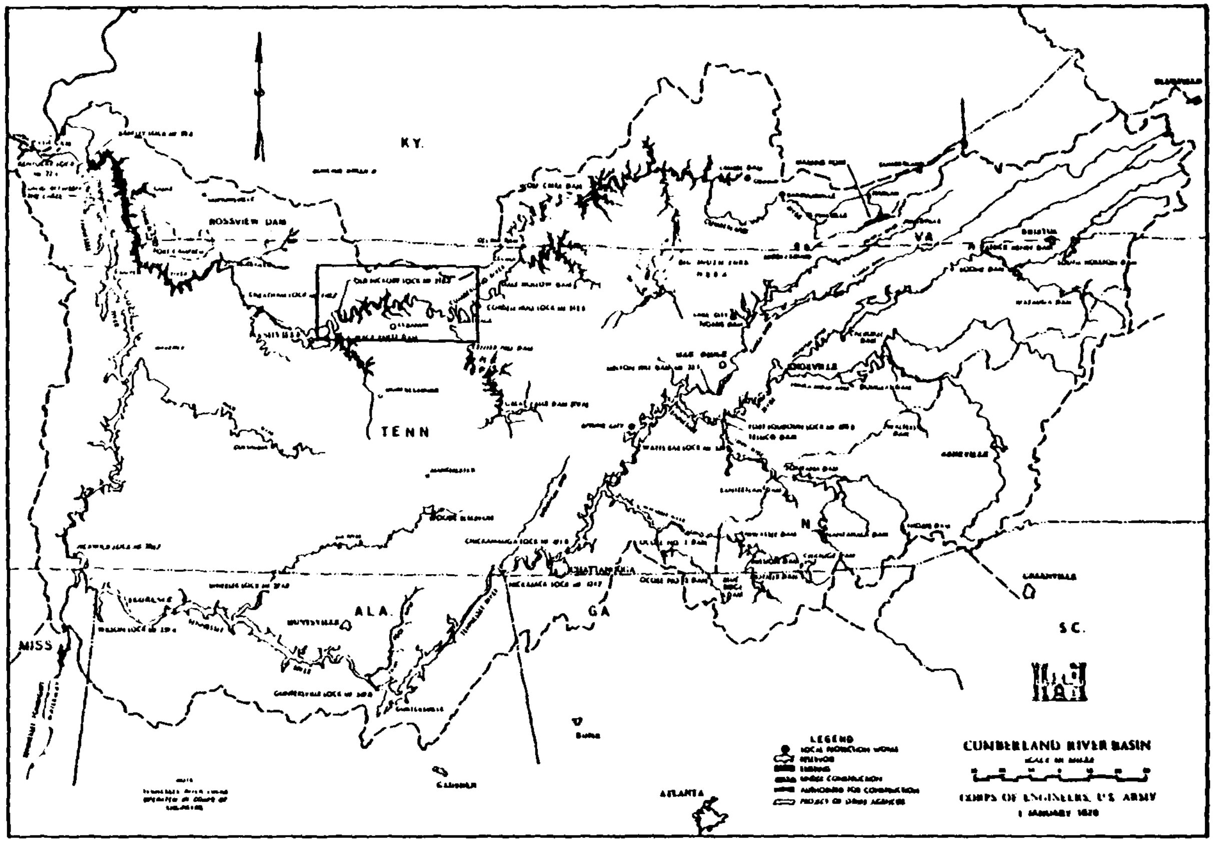
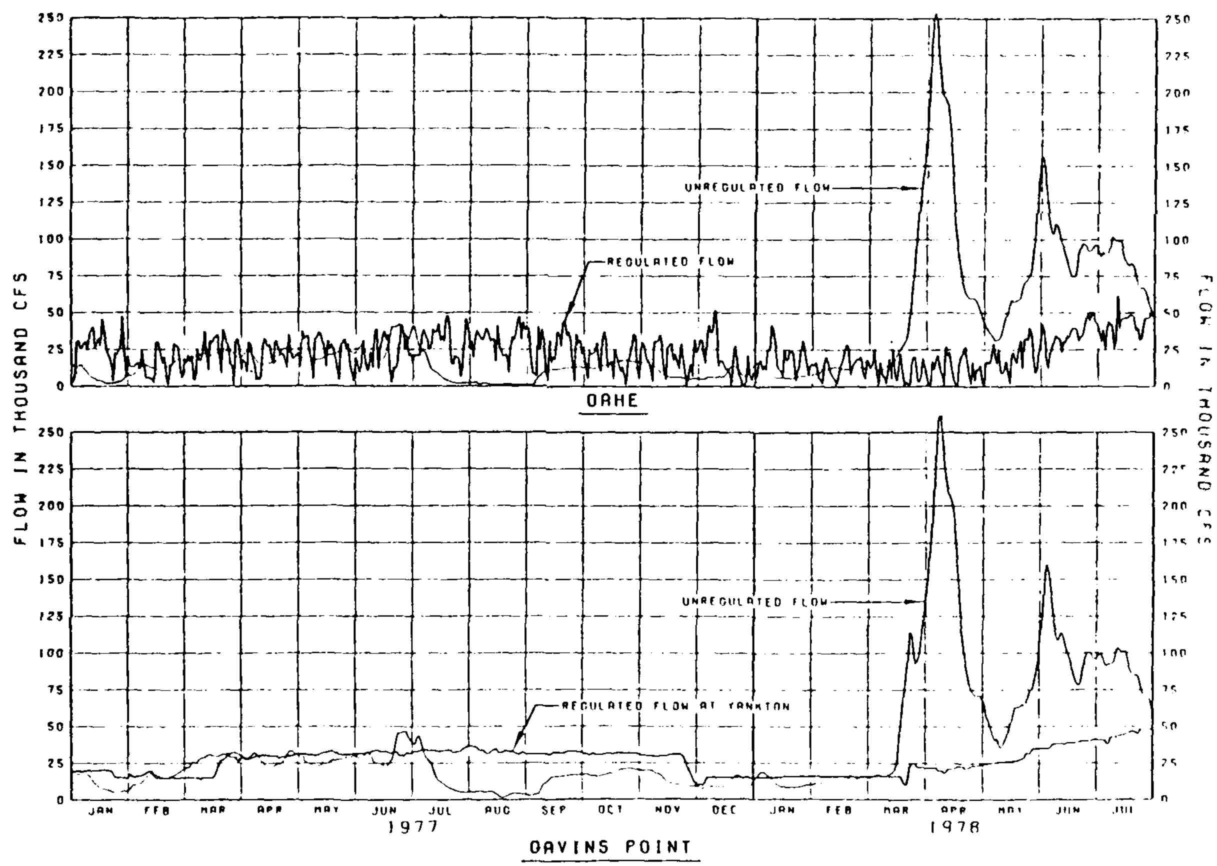


Figure IV-S

Missouri River Flows



because there is so much carryover storage in the main stem reservoirs. It would only be during a long-term drought that navigation flows would be reduced.

Conflicts between hydropower and navigation on the Missouri River are not significant for two reasons. First, during normal or wet years, there is enough flexibility in the system to meet peak demands and yet still have relatively constant releases for navigation. Second, during an extended drought, both navigation and hydropower would suffer equally while consumptive demands are satisfied. The top priorities of the Missouri system are to prevent flood damages and meet upstream consumptive uses. Hydropower and navigation have lower but equal priorities. During a long drought, hydropower and navigation needs would be satisfied, to the extent possible by the same procedures used under normal conditions. However, the navigation season would be shortened, as discussed in the case study of the Missouri in the preceding section.

7. Arkansas and Verdigris Rivers (Region 9). The Arkansas-Verdigris River system is navigable from its confluence with the Mississippi River to Catoosa, Oklahoma. (see map in Figure IV-E) There are 17 locks and dams which were constructed to maintain adequate depths and four of these have hydropower generating facilities. There are also other Corps and non-Corps projects off of the main stem which generate hydropower.

Operation of hydropower plants off of the main channel has not been critical to navigation on the Arkansas-Verdigris system. The pools have maintained adequate channel depths when the plants are shut down and have prevented excessive velocities during peaking periods. The four main stem hydropower installations also have not had any significant impacts on navigation, although they too are utilized to meet peak power demands. The pools have been able to insure sufficient channel depth during draw down and reduce peak velocities by damping out the fluctuations in discharge. As a result there have been no constraints on navigation on the Arkansas-Verdigris due to hydropower releases. Hydrographs of a simulation model of the system are shown in Figures IV-T and IV-U for Van Buren Lock and Dam. These releases are completely compatible with navigation.

Figure IV-T

Arkansas River Low Flow

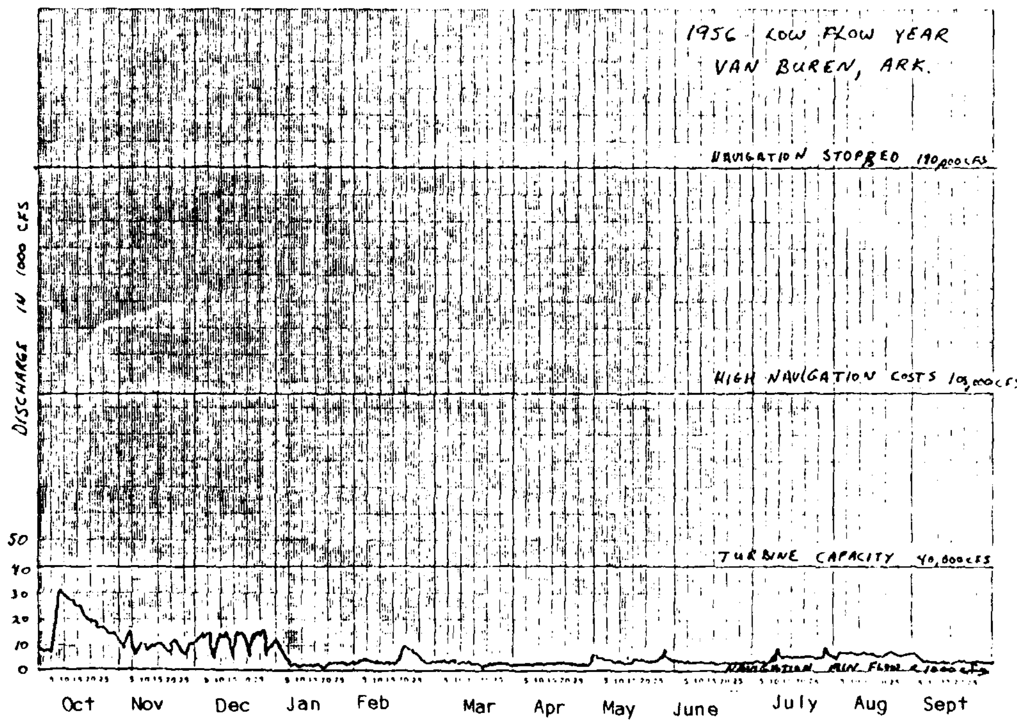
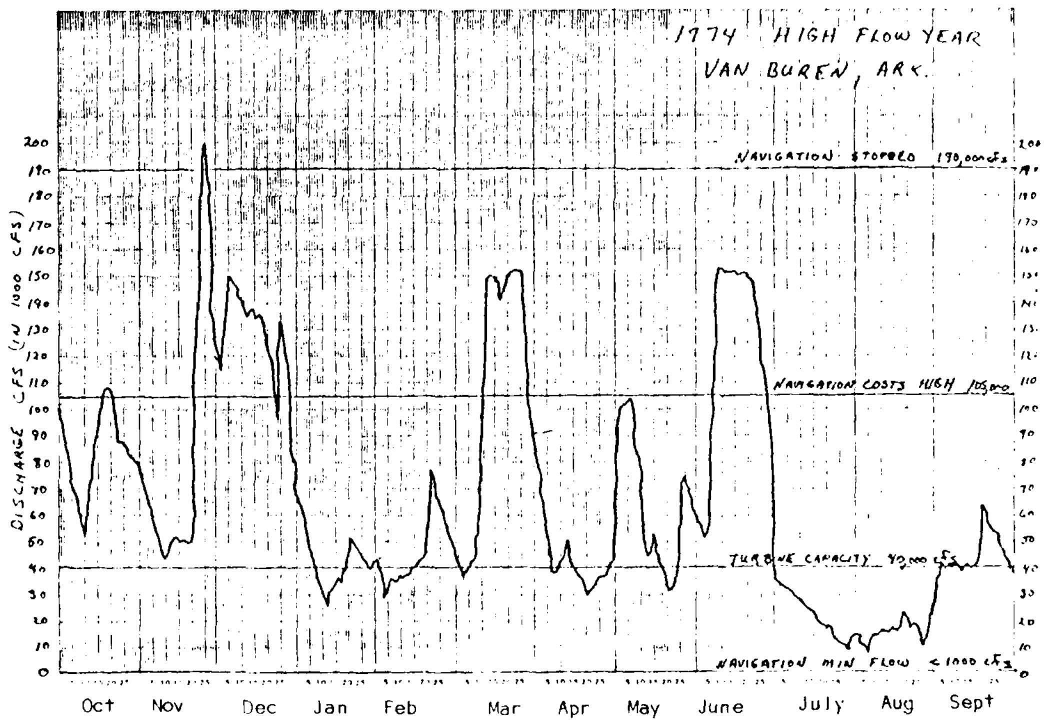


Figure IV-U

Arkansas River High Flow



8. Future Effects. The most significant factor which could affect the interaction between hydropower generation and navigation is the availability and cost of energy. As other forms of energy, such as fossil and nuclear, become scarcer and more expensive, the value of hydropower will rise in relation to other water uses. In areas of compatability between hydropower and navigation this should not pose a problem. However, in places where there are conflicts or tradeoffs being made between the two there would be greater competition. The constraints which have been identified on the Alabama-Coosa, Cumberland, and Columbia Rivers could be intensified as a result of this competition. Pressure to increase system efficiency by expanding peaking operations would have the greatest impact on these segments. On other segments, the hydropower operations appear to be well enough integrated with navigation so as to avoid any significant restrictions.

(c) Flood Control

1. Effect on Instream Flow. Flood control is not a use of water in the same sense as other instream water uses, but it does have very significant effects on the timing and magnitude of stream flows. The primary purpose of flood control, of course, is the protection of human life and to prevent damage to man made structures, crops, and lifestock located in the flood plain. This purpose is achieved through the use of storage space in reservoirs which is held empty in anticipation of high stream flows. When excessive rainfall causes increased stream flow, the reservoir is filled. After the storm subsides, the reservoir will be evacuated, at a rate not to exceed flood stage so as to be ready for the next flood. In practice it is much more complicated than described here since the reservoir operation must account for: snow melt, rain storms of various probabilities, instensities, and duration, and other water users. The effect however, is generally the same in that the peak flow rate is reduced and the flood waters are spread out over a longer period of time.

Reservoirs which are operated for flood control purposes experience large fluctuations in stage as flood water is stored and then emptied. As a result, these reservoirs can be unattractive for other uses such as recreation due to unsightly exposed banks and difficulty of access to widely changing shorelines.

2. Relation to Navigation Requirements. Flood control does not affect low or normal river flows except in the sense that retained flood waters are often used later for other purposes, such as low flow augmentation.

The only interaction between flood control and navigation is the result of reducing peak flows. Excessive stream velocities are always a constraint to navigation although the exact limit depends on such factors as river configuration, tow size, and tow horsepower. In canalized segments lock structures that could prohibit navigation can be flooded out. Flood control therefore complements navigation by reducing the incidence of high flow related constraints.

3. Segment Flows. Specific examples relating the results of flood control to navigation can be found in the graphs of Figures IV-A through IV-L. Each segment includes a hydrograph for the operation during a wet year. In the applicable cases a maximum navigation flow or the flow which floods the lock is noted. For all of these situations the peak flows would have been higher and longer without the existing flood control.

4. Future Effects. It is unlikely that reservoir operations will be modified in any way which would increase the incidence of peak flows and concomitant flood damages. However, as more non-structural methods for reducing flood damages are implemented there may be a tendency to less regulation of flood flows. Additional pressure to reduce the regulation of downstream flows could also come from other water users, such as recreationists, who desire less fluctuation in reservoir levels. A situation such as this could only occur where it could be clearly demonstrated that flood damages would not be exacerbated. Otherwise, downstream land owners will continue to press for reducing peak flows, which is complementary with navigation interests.

(d) Integrated Instream Flows

For each of the analytic segments with significant instream water uses a minimum stream flow envelope was prepared, for both an average and a dry year. The minimum streamflow envelope incorporates all of the complementary instream water uses into one annual hydrograph. If the

requirements of this curve (the instream flow envelope) are satisfied, then all instream uses should be satisfied since they are all less than the constructed curve, and they are all complimentary. Because the instream flows which are being evaluated in this task are all minimum required flows, the instream flow envelope represents the extreme minimum streamflow independent of navigation releases.

The minimum streamflow envelopes for significant analytic segments are shown in Figures IV-V through IV-AA. These graphs include all instream uses except for navigation and therefore show what flows would be like without any navigation releases. Because very few legal environmental instream flow requirements were indentified these graphs represent primarily hydropower releases or flood control operations. These envelopes constitute a minimum floor if instream flows which is generally complementary with navigation and would occur without any navigation related releases. For all of these segments, under present conditions, the minimum envelopes were sufficient for supporting navigation requirements.

(e) Conclusions

Hydropower releases lead to minimum instream flows in many segments as a result of meeting energy commitments. The volume of water in these releases is complementary with navigation requirements. The Cumberland River and Alabama-Coosa Rivers both have particular navigation problems due to fluctuation in hydropower releases in response to hourly and daily electrical demand variations. In the future, the problems on the Cumberland River and Alabama-Coosa Rivers could be intensified and duplicated on other segments as other energy sources become scarcer and more expensive, and hydropower is used more for peak power production.

Flood control operations serve to limit maximum flows and velocities in navigable channels. In this manner, flood control complements navigation since it reduces the number of days in which channels or locks are closed due to excessive water. The Alabama-Coosa waterway is the only segment which has been identified as having significant flooding problems. Little change is expected in

Figure IV-V

Columbia River, Minimum Flow Envelope

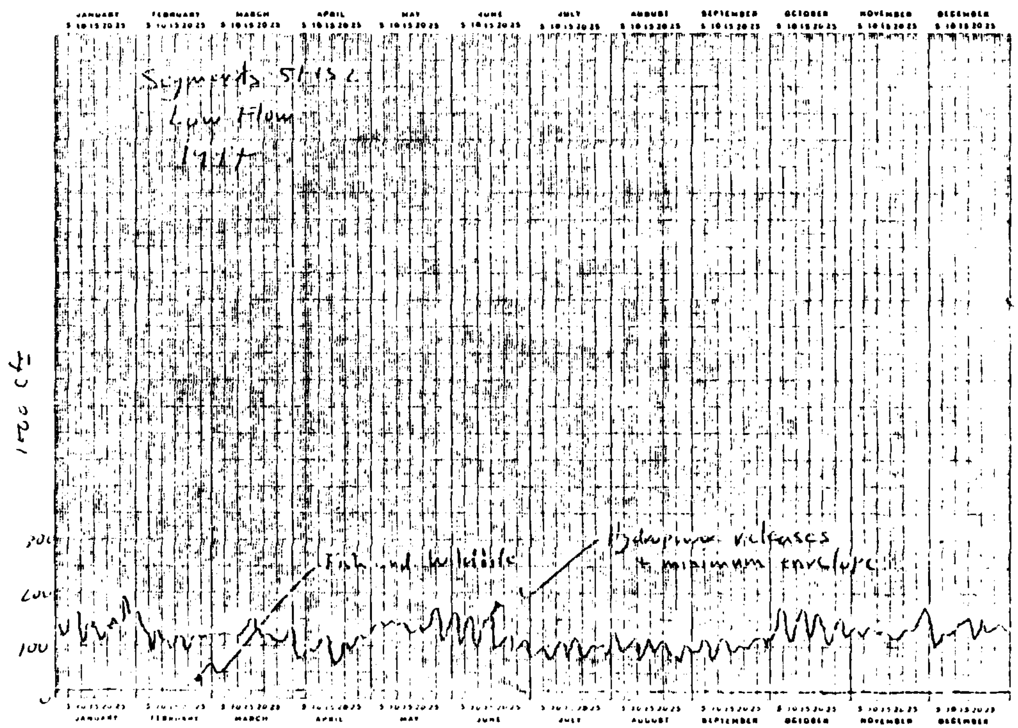


Figure IV-W

Apalachicola River, Minimum Flow Envelope

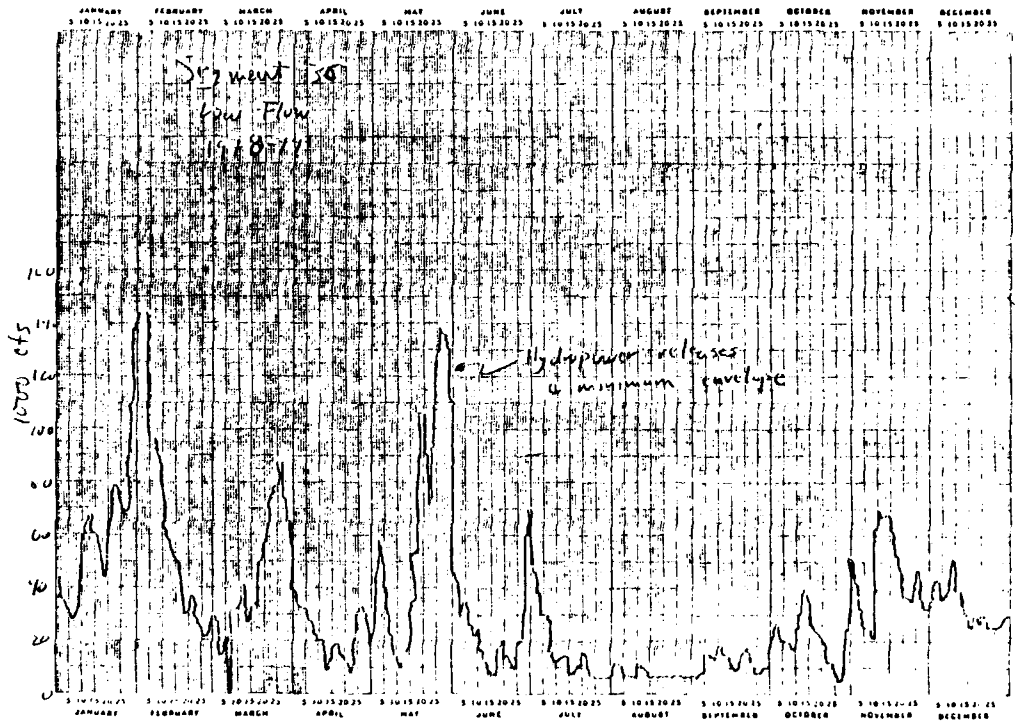


Figure IV-X

Tennessee River Minimum Flow Envelope

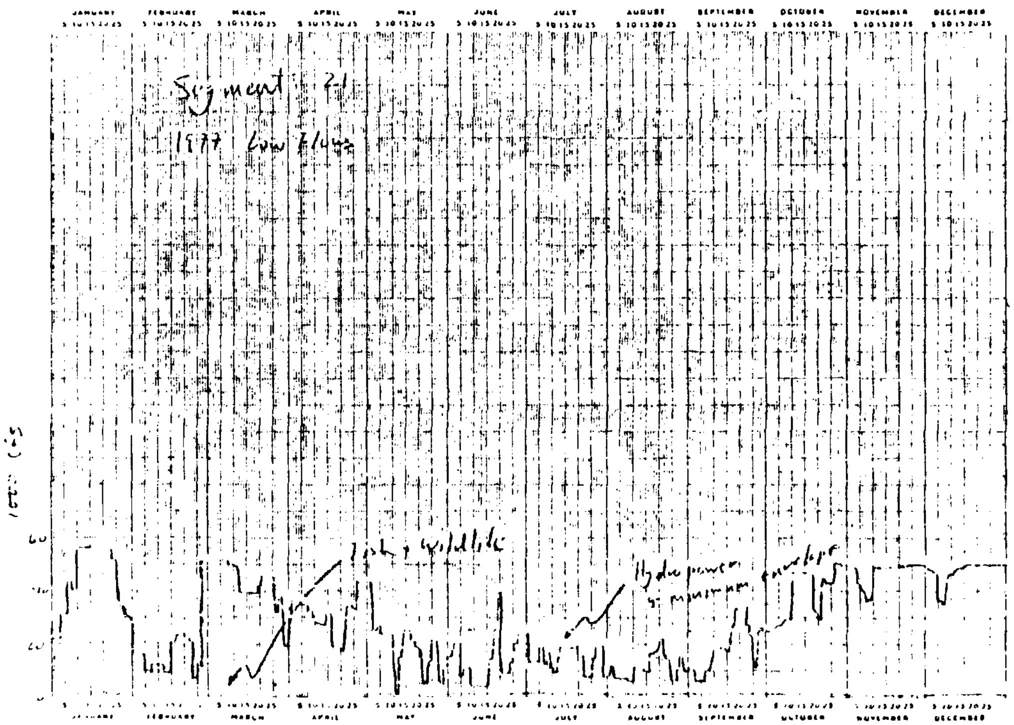


Figure IV-Y

Tennessee Valley Minimum Flow Envelope

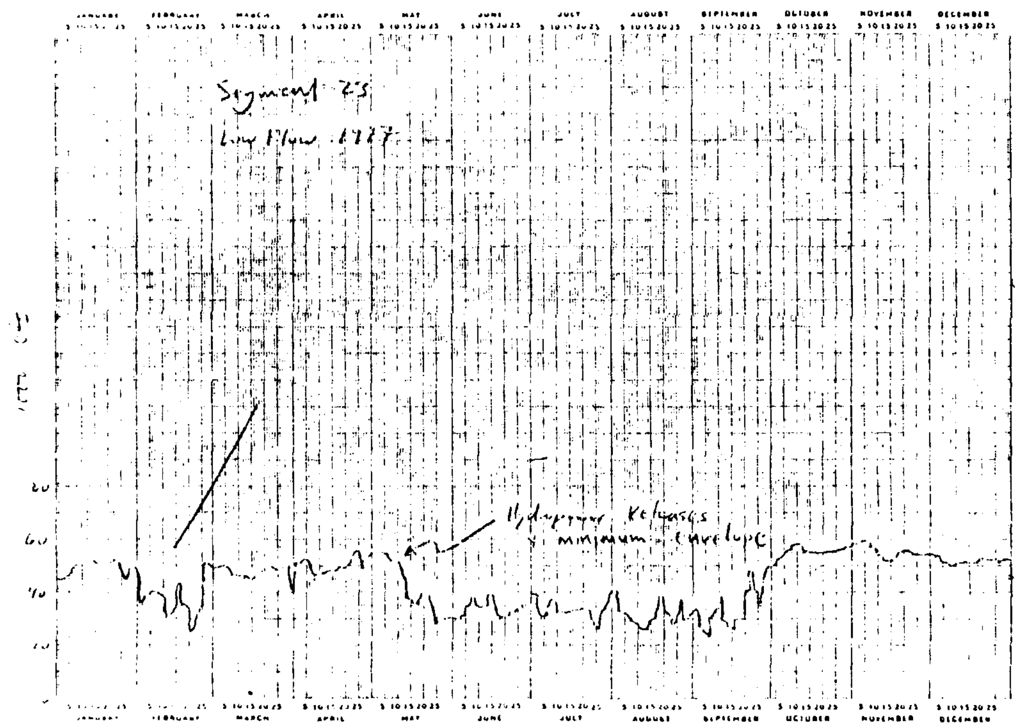


Figure IV-Z

Missouri River Minimum Flow Envelope

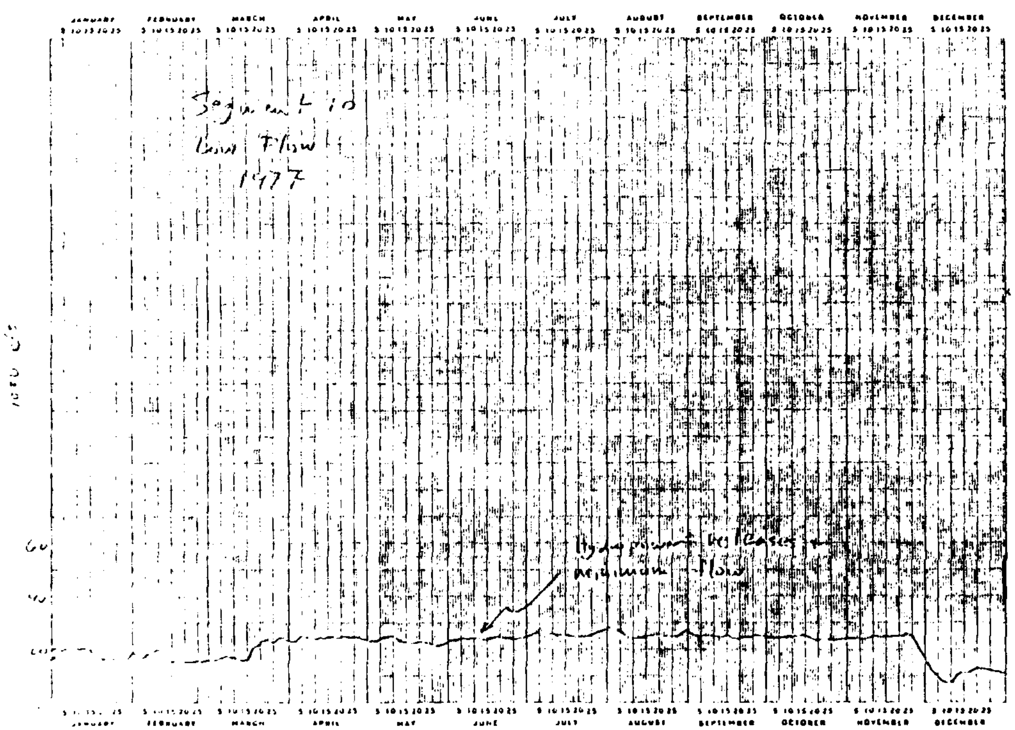
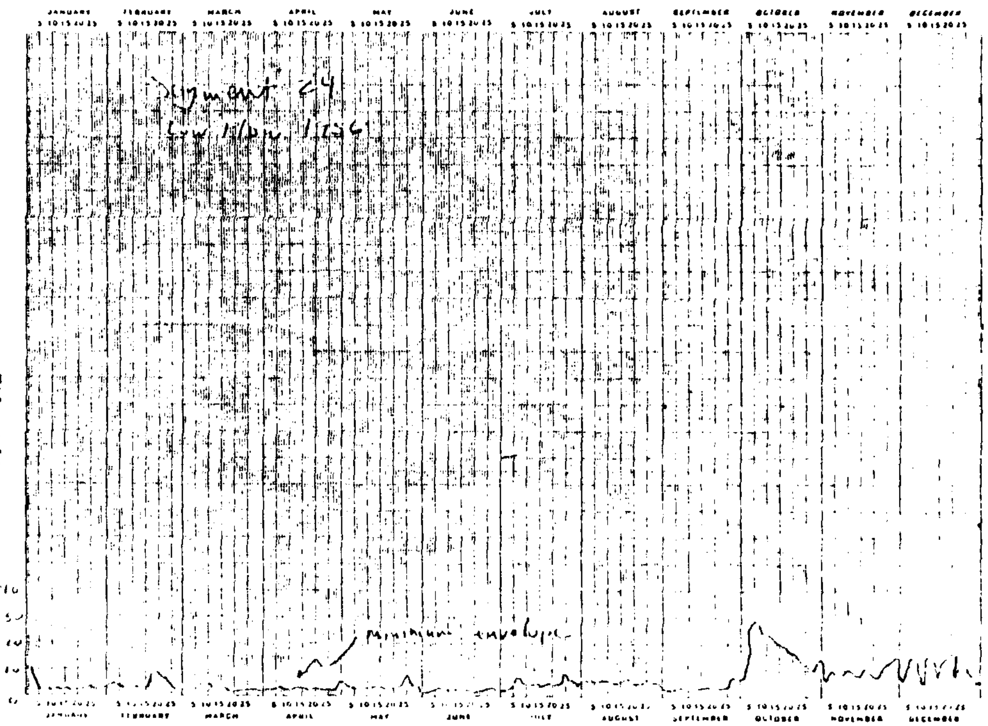


Figure IV-AA

Arkansas River Minimum Flow Envelope



future flood control operations although there will probably be some increase in nonstructural approaches (zoning or flood plain purchase) as opposed to structural, flow limitation strategies. Segment closings due to highflows were identified for 11 waterways.

Minimum flow requirements for fish and wildlife purposes can take many different forms because the demands of aquatic organisms are so varied. Minimum flows established on a water quality basis have much less fluctuation. All of the environmentally related flow requirements are complementary with navigation except in limited cases where there are large seasonal variations in the flow demand. However, there are very few cases of legally enforceable instream flows for environmental purposes. Priest Rapids Dam on the Columbia River system is required to relsease 36,000 cfs and Hell's Canyon Dam has a minimum flow requirement which varies seasonally. Other environmental minimum flows such as 1000 cfs on the Cumberland River, and 6500 cfs on the Alabama River, do not have legal status but are informal agreements or targets which are satisfied as long as there is sufficient water. In the future, there may be a minor increase in the number of segments with environmental flow criteria, but these probably will not significantly impact navigation.

For each of the segments analyzed, a graph of the minimum instream flow envelope was prepared, incorporating the effects of all instream flow uses and establishing an annual hydrograph of minimum expected flow at all times on the segment. This minimum flow envelope will occur without any navigation releases and is generally complementary to any navigation requirements. On all of the analyzed segments, the minimum instream flow envelope was sufficient to satisfy the average monthly navigation requirements in low flow periods in recent years, although hydropower release schedules create navigation problems on a weekly or daily basis on the Alabama, the ACF and the Cumberland.

Specific conflicts presently arising from instream flow uses were identified in sections on fish and wildlife, hydropower, and flood control. The only problems which were identified are mostly localized and relate to the timing of hydropower releases. These short-term

hydropower surges or daily fluctuations in releases are constraints to navigation on the Cumberland and Alabama-Coosa Rivers.

Effects of future instream flow uses should not be significantly different from present impacts on an average monthly level. However, it is possible that rising energy costs and increasing energy scarcity could place a greater emphasis on hydropower peaking. Increased peaking operations at the expense of off-peak releases will cause concern for navigation interests in certain cases. Segments where conflicts are most likely to occur are the Cumberland and Alabama-Coosa Rivers which already experience these types of problems. Run of the river hydropower installations have no impact on navigation since they do not change the timing of streamflow.

V - SALT WATER INTRUSION

This topic is different from others in this report because it relates to the indirect effect of Corps actions on salt water intrusion. The salt water intrusion in turn can affect irrigation water supply, municipal or industrial water supply, and estuary conditions for fish and wildlife habitat.

Three separate segments in three regions were selected for case studies in order to examine the range of problems on the United States waterway system. These were San Francisco Bay/Delta (Region 19), GIWW West I (Region 10) and the Chesapeake and Delaware Bays (Region 14).

METHODOLOGY

The methodology employed in this study focuses upon three selected waterway segments where salt water intrusion concerns related to navigation have been identified, and it identifies possible strategies, both structural and operational, that could be employed to control salt water intrusion.

The analysis essentially summarizes available secondary data and modeling efforts and relates these to navigation projects. Visits were made to the San Francisco, Sacramento and New Orleans districts and phone contact was made with the Baltimore and Phildadelphia districts. Extenisve use was made of Corps documents, particularly EIS reports and General Design Memoranda, on various projects both completed and proposed.

Hydraulic model results were found to be particularly useful in the case of the San Francisco Bay/Delta. Modeling studies pertinent to salt water intrustion have not been undertaken on GIWW West I segment. While modeling of the Chesapeake Bay area has been completed, the results are presently under review.

There have been some indications of data weakness in describing the full impacts of salt water intrusion. This

is particularly true in describing the effects of salinity variations on aquatic life, both fish and plant life. There appear to be significant gaps in understanding the exact ecological conditions that many marine organisms require. This had precipitated controversies over the actual effects that a particular project may cause, especially where only small changes in salinity are forecast.

Hydraulic models have also been subjected to certain criticisms. The San Francisco Bay/Delta model results have been questioned as to whether the steady state results provided are valid for a dynamic situation. The modeling of water withdrawals from the channel has also been questioned because many assumptions are unverifiable. The model has also been criticized for its use of generally "simplified hydrology." The latest modeling study of the San Francisco Bay concludes that salinity changes are smaller than the model can accurately predict, which leaves open the possibility of further debate on this issue.

Salt water intrusion is difficult to specify because it is found in a pattern of varying concentrations over each estuary area; it varies also by depth within each water body, and from season to season, depending on freshwater flow.

For the purposes of this study, salt water intrusion is defined as: 1) an increase in salinity of groundwater at a given location and depth or 2) the change in location along a channel of a salt water wedge, produced by acts of man. Acceptable levels of salinity as a water quality parameter will depend upon the proposed water uses.

Salinity is most commonly expressed in units of total dissolved solids (TDS) or chlorinity. Sea water, for example, averages about 35,000 ppm (parts per million) TDS and 19,000 ppm of chlorinity. The upper limit of salinity for municipal supplies is 500 ppm of TDS and 250 ppm of chlorinity. The agricultural limits of salinity vary with the crop, irrigation practices, and drainage. Crops such as grains, pasture, sugar beets, and asparagus are salt tolerant, while most varieties of rice are very sensitive to salt water. Industrial water quality requirements vary

widely depending on the product and industrial process. Many industrial users, such as the food and beverage manufacturers, require the same standards as drinking water, while other industries which require larger volumes of water for cooling purposes, for example, may utilize water which is highly saline. The fauna and flora of estuaries are characteristically tolerant of wide ranges of salinity, but nevertheless have definite preferences which often vary during their life cycle.

ANALYSIS OF CASE STUDY SEGMENTS

(a) Chesapeake and Delaware Bays

1. Environmental Description. The Chesapeake Bay, with its tributaries, constitutes one of the largest and most economically important estuaries in the world (64,000 square miles). With waterborne commerce totaling 160 million tons in 1974, a seafood industry with a yearly harvest valued at $48 million in 1973, and highly intensive recreation use, the Bay forms a vital link in the economic cycle of the mid Atlantic region.

The surface area of Chesapeake Bay is about 4,400 square miles with 7,000 miles of shoreline (see Figure V-A). Fresh water inflows for the Bay are provided by five major rivers, which account for 88% of the mean annual inflow of 69,800 cfs. These are the Susequehanna, Potomac, Rappahannock, York, and James Rivers.

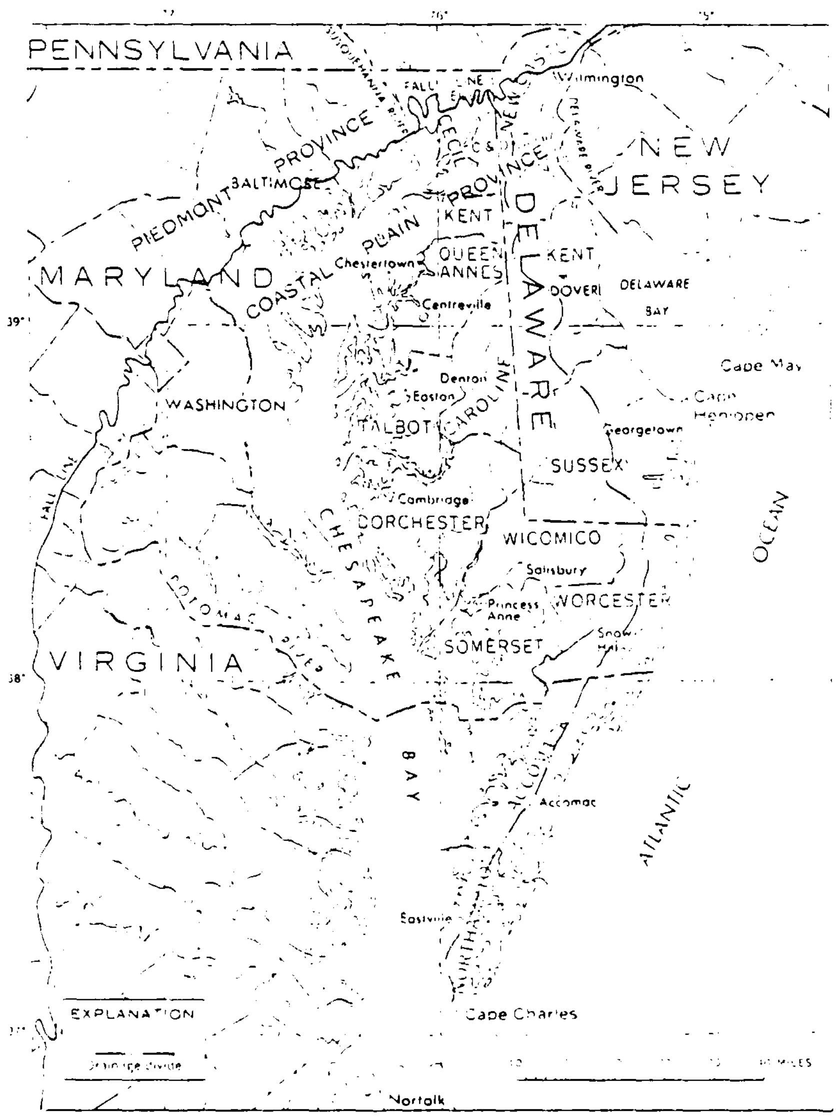
The overall quality of water in the Bay is considered good, but local pollution has been found depending on the proximity to urban areas and the type and extent of industrial and agricultural activity.

Most of the severe problems are in the tributaries of the Bay, especially near areas of high population concentration. Increasing loads from sewage treatment plants and industrial sources, as well as from agricultural and storm runoff and marine transportation spills, are causing stresses and problems throughout the Bay region.

Navigation facilities have been highly developed on Chesapeake Bay and its tributaries and are expected to continue to grow. There are a total of 147 authorized

Figure V-A

Chesapeake and Delaware Basins



navigation projects in the Baltimore and Norfolk districts of the Corps. The State of Maryland has constructed 16 additional navigation projects. There are two major deep-water ports in the Chesapeake Bay at Baltimore and Hampton Roads with depths of 42 and 45 feet, respectively. Baltimore harbor has been authorized to be deepened to 50 feet and Hampton Roads is being studied for a depth of 55 feet. The deepening of channels is considered a major need for navigation in the Bay in order to accommodate the larger ships now in the world fleet.

The demand for water in the Chesapeake Bay area in 1970 was 2,460 million gallons per day (MGD). Of this total, 900 mdg is brackish water used in industrial processes, 122 mgd is reused municipal wastewater, and the remaining 1,438 mgd is freshwater from ground and surface sources. By the 2020 the demand for water supplied through central systems is projected to increase by approximately 170% according to the Chesapeake Bay Future Conditions Report. This will require, in many locations around the Bay, the development of new sources of supply, including both surface and groundwater. This increase in demand will tend to draw down aquifer water levels and facilitate salt water intrusion.

The Delaware River and its tributaries covers a drainage basin of 12,765 square miles. Most of the basin is moderately rolling with the highest elevations reaching 4,000 feet. The Bay itself is 48 miles long and is tidal as far inland as Trenton, New Jersey. The Delaware Bay and the Chesapeake Bay are connected by the 14 mile long Chesapeake and Delaware Canal. A map of the Chesapeake and Delaware basins is shown in Figure V-A.

The water resources of the Delaware River Basin are utilized by over 25 million people. This high density of population consumes about 3.5 billion gallons of water a day for use by municipalities, agriculture, and industry and an additional 3.4 billion gallons are used for cooling purposes by power generating plants. While population of the Delaware Bay region is already high, it is expected to double in the next 50 years and water demand is projected to increase even more. Some estimates place the water need at 14 billion gallons daily by the year 2010 and power generation would require 38 billion gallons[3] (COE, 1977). Such estimates and the experience of several severe droughts in the past 25 years have emphasized the need for additional water storage capacity in the basin.

2. <u>Salt Water Intrusion in the Chesapeake and Delaware Basins</u>. The water of the Chesapeake and Delaware basins is generally of excellent quality. Point values of water quality vary considerably with time and location. Variations of quality with time are influenced by stream flow. Stream flow in the Chesapeake and Delaware basins is generally low in total dissolved solids (TDS) and suitable for most uses except in the downstream reaches of those streams subject to tidal invasion of saline water.

The TDS for the Choptank River, a typical tributary to the Chesapeake Bay, is less than 100 ppm and falls below 70 ppm for high stream flows (500 ppm is the maximum standard for drinking water). Chlorinity varies only slightly with stream flow as it is present in small concentrations of less than 10 ppm in freshwater reaches (250 ppm is maximum standard for drinking water).

The following quote from the Chesapeake Bay Future Conditions Report[4] describes the seasonal variation in salinity.

> "Due to this seasonal variation in salinity and the natural density differences between fresh and saline waters, significant *non-tidal circulation* often occurs within the Bay's small tributary embayments. In the spring, during the period of high freshwater inflow to the Bay, salinity in the embayments may be greater than in the Bay. Because of this salinity difference, surface water from the Bay flows into the tributaries on the surface, while the heavier, more saline bottom water from the tributaries flows into the bottom of the tributaries, while tributary surface waters flow into the Bay.
>
> The natural variations in salinity that occur in the Bay are part of the dynamic nature of the estuary, and the resident species of plants and animals are ordinarily able to adjust to the changes. Sudden changes in salinity, however, or changes of long duration or magnitude may upset the equilibrium between organisms and their environment. Abnormal periods of freshwater inflow (i.e. floods and droughts) may alter salinity sufficiently to cause widespread damage to the ecosystem."

The Delaware and Chesapeake Bays, their tributary estuaries, the Chesapeake and Delaware Canal and, of course, the ocean all contain varying concentrations of saline water. Fresh groundwater moves through the aquifer and, with the natural hydraulic gradient, moves toward these saline surface water bodies. The fresh water gradient is generally sufficient to revert landward movement of saline water into the aquifer. It appears likely that the fine grained sediments found at the bottom of the bays and estuaries have prevented the downward movement of saline water where excessive pumping has occurred.[5]

In the Baltimore district there have been several instances of pumping for municipal and industrial purposes, which has reversed the normal hydraulic gradients and caused saline water to migrate landward. These include the municipal water supply pumping at Suffolk, Virginia; an industrial papermill the Union Camp, and Northern Anne Arundel County, Maryland. In addition, there is a possibility of problems at Lewes and Dover, Delaware. However, there have been instances of salt water intrusion problems associated with navigation projects.

3. <u>Chesapeake and Delaware Canal</u>. There have been several studies completed by the Corps to determine the possibility of salt water intrusion into freshwater aquifers as a result of channel deepening in the Chesapeake and Delaware (C&D) Canal for navigation purposes. The C&D Canal was first built in 1829. In 1938, the canal was enlarged to a depth of 27 feet and widened to 250 feet. In 1954, the canal was authorized to be enlarged to 35 feet deep and 450 feet wide. Concern was expressed about the possibilities of salt water intrusion from the deepening project and the Corps subsequently completed several studies over the course of its construction (COE, 1973).

The first study, completed in 1958 when the work of widening and deepening had just commenced, indicated that positive hydraulic gradients led toward the canal. The gradients were low and somewhat obscured by tidal fluctuation, which affected the water table elevations in wells near the canal. No correlation was detected between the quality of water in the wells and that of water in the canal. The study concluded that enlargement of the canal by widening, deepening and straightening the channel may result in the opportunity for salt water intrusion, but

sufficient data to calculate these effects were not available.

A second study, completed in 1967, at which time the work of widening and deepening was 57% complete, identified an aquifier, the "Potomac" formation, underlying the whole canal area and forming the main source of moderate supplies of groundwater. The report concluded that the deepening and widening of the canal would probably not have any degrading effect on the quality of the groundwaters in the aquifirs under or along the canal.

The third study, completed in 1971 when the work of widening and deepening was 87% complete, concluded as follows: 1) although the canal-carried salt water has crossed groundwater reservoirs since 1919, there has been no contamination of groundwater reservoirs by salt water in the canal, 2) the hydraulic gradient is toward the canal; thus, groundwater reservoirs are actually discharging into the canal and water from the canal is not contaminating the aquifers. The study concluded that the maintenance of the hydraulic gradient in the present direction is essential; that it could be reversed by withdrawing water from the groundwater reservoirs. Wells drawing water from the upper zone should not be drilled close to the canal. This condition represents a constraint on any industrialization in the existing farm area and requires proper regional planning to avoid excessive pumping.

Further studies were undertaken by the Chesapeake Bay Institute and the Corps Waterways Experiment Station (WES) on surface water over many years. These studies concluded that the deepening project will not affect the inflow of freshwater from the Susquehanna River to the Upper Chesapeake Bay. The final EIS, "Inland Waterway Delaware River to Chesapeake Bay," states:

> "The salinity generally increases from a minimum at the Chesapeake end to a maximum at or near the Delaware end of the Canal. Enlargement of the Canal will not change this general spatial pattern. The general time variation in salinity, with minimum salinities in the spring during and immediately following the period of high freshwater discharge from the Susquehanna and maximum salinities in the late fall following the usual prolonged period of low freshwater inflow to both the Chesapeake and Delaware, will also not be

altered. The enlargement of the Canal will, however, result in a slight shifting of the salinity gradient eastward. It will result in a slight eastward displacement of the region of "freshwater" in the Canal. It was previously demonstrated that the early estimates of the increase in average net non-tidal flow through the Canal due to enlargement would not result in a change in the salinity distribution in the Chesapeake Bay during the critical spring time spawning period of Striped Bass and that the increase in salinities which would occur during the periods of low freshwater inflow to the bay would be of insufficient horizontal extent or time duration to have any predictable biological effect."

At the present time the Corps is continuing its studies in the post project phase of the canal deepening. There have been no indications of salt water intrusion into the associated aquifers. Most concerns are centered around the effects, if any, on the fisheries of the estuaries, particularly the shellfish.

4. Other COE Studies Related to Salt Water Intrusion. An extensive investigation of water use and control within the Chesapeake Bay Basin is underway. The investigation is making use of the Chesapeake Bay Hydraulic Model. The study will include the effects of low stream flow and salt water intrusion. This study will provide some insights into possible changes in the salt water regime of Chesapeake Bay, but no results are available at this time.

A study is underway on the effects of salinity intrusion in the Delaware estuary. The specific goals of this study are to determine a) the probability of advance or retreat of salinity in the Delaware estuary and b) the quantity of freshwater inflow needed to protect the various water users along the estuary. The various users include 1) domestic, commercial, industrial, and institutional customers of municipal water supply systems, 2) industrial users that withdraw water directly from the Delaware estuary, and 3) fish and wildlife resources.

Groundwater pumping in several locations in the Delaware Basin is considered to be close to its safe yield. Further pumping may affect the base flow of the

river and increase the possibility of salt water intrusion, although no such situations have developed to date. Future strategies to control water quality have been suggested, including requiring that major industrial water users, power companies in particular, provide upstream storage of water for low flow augmentation. Other strategies include providing incentives for water conservation.

Another study which is underway concerns deepening of the Baltimore Harbor. Deepening to 50 feet is proposed and concern has been expressed about its effect on salinity conditions in the bay. Most of the concern relates to the project's effect on fisheries habitat.

5. Conclusions. Salt water intrusion and its possible effects upon navigation appears to be related to future conditions of stream flow and groundwater pumping. Although there have been no significant cases of salt water intrusion because of Corps projects related to navigation, concerns have been expressed and several instances of possible future effects have been documented.

Groundwater supplies, with the exception of those sites previously mentioned, have generally not been subjected to excessive pumping, and freshwater gradients remain in a seaward direction. The Chesapeake and Delaware Bays also appear to benefit from impervious strata which act to confine the saline waters. Dredging activities must insure careful attention to avoid damage to this sediment layer.

Surface water supplies are projected to decrease in the future because of increased consumption. The combination of decreased flow and the periodic occurrence of droughts will probably allow upstream penetration of salt water to new levels. The augmentation of low flows through increased upstream storage appears to be the most plausible strategy if predicted consumption levels are reached. Should the municipal water supplies of Philadelphia or other locations be fouled because of salt water intrusion, mitigation measures are possible. These could require changes in the water supply intake location or the provision of alternate sources of supply. Such mitigation would be extremely costly given the projected limitations placed upon future water availability in the Chesapeake and Delaware region.

The primary impact of changes in estuarine salinity conditions would be upon the shellfish and other fish and aquatic life. Long-term salinity changes from reduced freshwater flows or changes in channel dimensions would probably cause certain fish to move to less saline locations. This could potentially impact the fishing industry by moving the fishing grounds to areas where they might conflict with other users, such as recreation or navigation.

Due to the environmental concern expressed over the deepening of the C&D Canal and salt water intrusion resulting from projects in other parts of the country, it appears probable that future port and channel deepening projects will require thorough and detailed studies of potential salt water intrusion and mitigation measures before final authorization is granted. The effect on salt water intrusion of activities associated with a navigation project can only be judged on a case by case basis. Specific effects are purely conjecture in the Chesapeake and Delaware Bays at the present time. However, it is clear that any possible adverse effects will require mitigation and the cost of such measures may be considerable.

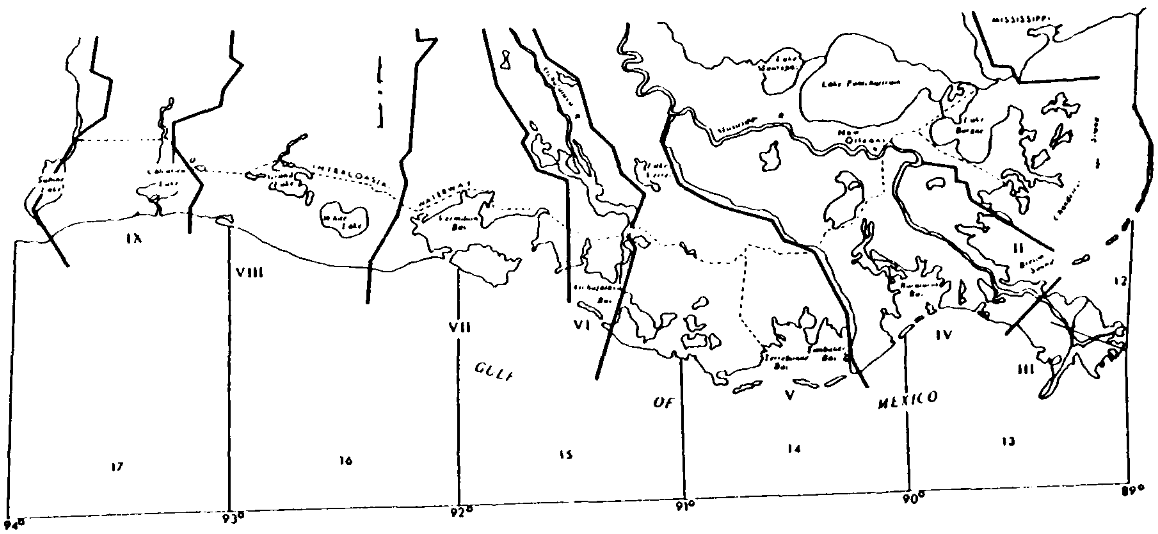
(b) GIWW West I (New Orleans to the Calcasieu River)

1. Environmental Description. The Gulf Intracoastal Waterway (GIWW) from New Orleans to the Calcasieu River generally follows the northern edge of the Louisiana coastal marshes. There are numerous interconnecting navigation channels between the GIWW and the Gulf that pass through the coastal marshes as well as the Mississippi River and its navigable channels, which pass through the same coastal zone (see Figure V-B). Because such developments are generally confined to natural levees, significant overall changes in the marshes resulting from development have not been reported. Pollution from inadequate sewage and refuse disposal has, however, damaged fishery resources in adjacent marshes in some areas.

Petroleum and natural gas production in the coastal and Offshore Continental Shelf zones make Louisiana the second largest producer in the United States. However, Louisiana's production is declining significantly, particulary in the coastal zone, as more emphasis is being placed on offshore drilling. The

Figure V-B

Gulf Intracoastal Waterway



coastal zone is expected to continue to serve as an important staging area for offshore operations, however, and this activity has been linked to navigation in the past.

The majority of canals in the estuarine zone have been constructed to facilitate oil and gas production. Previously, competition between petroleum firms resulted in a decision by each firm to construct and maintain its own canals. Consequently, many canals in estuary areas were constructed without regard for exisiting canals, resulting in needless duplication. In addition, spillage from oil wells has adversely affected the productivity of the estuarine zone.

Waterborne transportation is another of the major industries along the Louisiana coast. Although there are numerous ports located throughout the coastal zone, the major concentration of navigation facilities is located in the New Orleans-Baton Rouge metropolitan areas. The navigable waterways of this area are divided into 10 major reaches. Four of these area maintained at depths to accommodate shallow and deep traffic, the other six segments serve shallow-draft commerce only. The four deep-draft segments include: 1) Mississippi River-Gulf Outlet, 2) Mississipppi River (New Orleans to Head of Passes), 3) Mississippi River (Baton Rouge to upper limits of Ports of New Orleans), and 4) Inner Harbor Navigation Canal (Industrial Canal). The major component of the shallow-draft navigation network is the Gulf Intracoastal Waterway. The Barataria Bay Waterway, Bayou Lafourche and Lake Pontchartain navigation systems make up the remaining three waterway segments.

2. Salt Walter Intrusion in Coastal Louisiana. In the past, water salinities in coastal Louisiana were generally characterized by relative stability, particularly with respect to the transition from fresh to saline zones, and by gradual salinity change during and after floods. This was due in large measure to the length of the flood season and the network of natural drainage channels which served to buffer the effects of both the tidal influx of saline water and the input of freshwater runoff. This tempering of the effects of floods and tides, and the prolonged flood season, served to maintain areas of low salinities that were much larger than such areas are today.

Levee construction, with the resulting discharge of most of the flow of the Mississippi River directly into deep water in the Gulf of Mexico, has greatly diminished the quantity of freshwater entering the marshes. The extensive channelizaton of the marshes for navigation and drainage has increased the rates of freshwater runoff and tidal exchange and provided avenues for the intrusion of salt water. These developments have resulted in a long-term trend toward increased salinities in certain areas of the marshes, notably in areas out of the active delta.

In the Cheniere Plain zone, however, increased flows from the Atchafalyaya River through Wax Lane Outlet, the maintenance of freshwater reservoirs in the Mermentau Basin, and marsh management practices for wildlife refuges have tended to reduce salinities. Such trends indicate that the determination of long-term changes cannot be dealt with for the entire coastal marsh as a unit, but rather must be considered on an area basis. Perhaps the best indicator of long-term changes in salnity is the development of patterns of vegetative types which, in general, can be closely correlated with salinities.

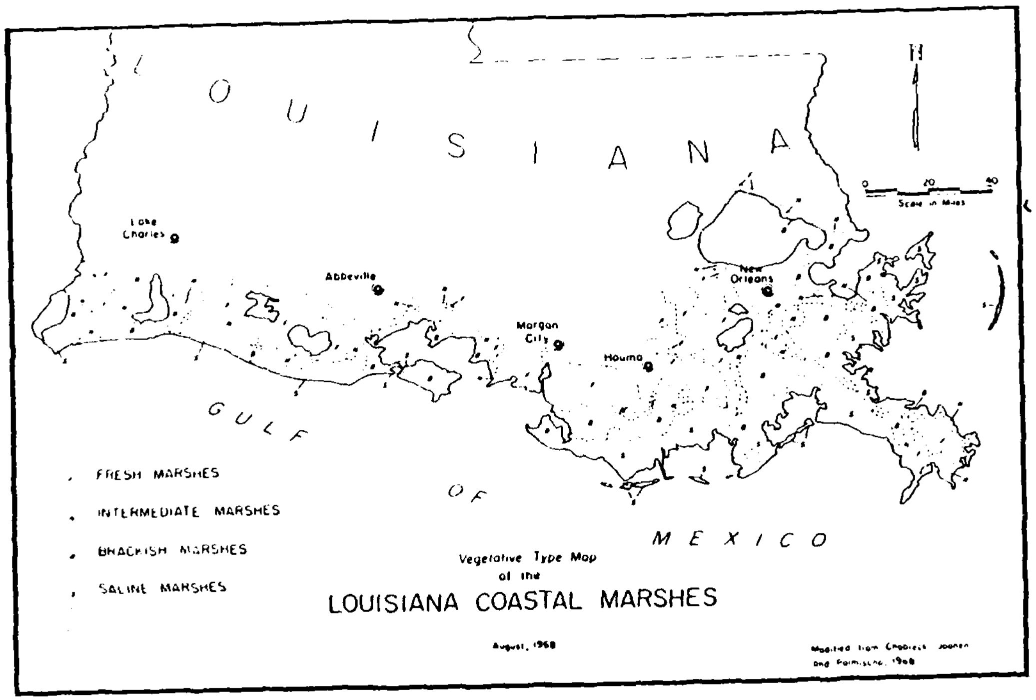
The Louisiana coastal marshes over 4.2 million acres of the coastal zone. Marshes have been divided into four types (fresh, intermediate, brackish, and saline), based upon their relative salinities. The location of each of these marshes is shown in Figure V-C.

Saline marshes comprise approximately 22% of the coastal zone. They are subjected to diurnal tidal fluctuations and are dissected by numerous embayments and tidal inlets. Saline marshes form a narrow band of only a few hundred yards along the western coastline, but may be very extensive in the eastern marshes. Water salinities of the saline marsh generally range above 20 ppt (parts per thousand). Saline marshes are considered to be highly productive areas providing a great deal of the necessary energy source of the fod chains of the Gulf estuarine complex.

Brackish marshes comprise 31% of the coastal zone. Tidal influences are less and water depths usually greater. Salinities range from 10 to 20 ppt and vegetation of brackish marsh is more diverse than saline marsh. Brackish marshes, like saline marshes, serve as important nursey and rearing areas for many species of fish and shell fish.

Figure V-C

Louisiana Coastal Marshes



Intermediate marshes cover 16% of the Louisiana coast. They generally exist as a narrow band between the brackish and freshwater marshes and have relatively low salinities of five to 10 ppt. Intermediate marshes are distributed throughout the hydrologic units. Saline intrusion has reduced the intermediate marsh types throughout Louisiana. They have been drastically reduced in the Lake Pontchartrain-Lake Borgre area since the construction of the Mississippi - Gulf Outlet Channel.

Fresh marshes cover 31% of the coastal marshes with relatively low salinities, less than five ppt. The vegetation is diverse, providing preferred habitats for waterfowl and furbearing mammals. Fishery productivity is lower than in the brackish or saline marsh types. Most of the GIWW lies within the freshwater marsh zone.

There are a number of identified surface water quality problems in southern Louisiana, including salt water intrusion and pollution from industrial and agricultural sources. These water quality problems are largely the result of man's presence in southern Louisiana and associated development.

Extensive engineering modification of surface water flow patterns has affected an estimated 75% of the streams in the Louisiana coastal region. The GIWW and associated canal systems have provided direct channels for the flow of freshwater from wetland areas into the Gulf. The result of the engineering modification of the surface drainage system is a reduction in surface freshwater levels and consequent salt water intrusion into freshwater areas. Channelization of the drainage system has also greatly reduced the occurrence of flooding in wetland areas. This is detrimental to wetlands in that flooding normally supplies nutrients to these areas. In some cases, however, the wetland areas have been improved by increased water circulation in stagnant areas.

Except for a few localized areas which show a trend to increasing average salinities, reliable long-term data on salt water intrusion are not available. However, according to studies by Hershman (1973) there are a variety of other indicators which attest to the magnitude of the problem. The dieback of cypress trees on Lake Pontchartrain, Houma Navigation Canal, and Falgont Canal has been attributed to increasing salinities, as cypress trees are intolerant of salinities above 1 to 2 ppt. Heavy

industrial withdrawals of groundwater in New Orleans, Baton Rouge and Lake Charles have resulted in salt water encroachment in local aquifers, and the accelerated withdrawal of groundwater in the Vermilion River basin for rice farming has also resulted in marked salt water intrusion[6]. Other factors contributing to the encroachment of saline waters in coastal Louisiana include the extensive flood control works (such as levees), which result in local shortages of freshwater, and increased channelization and canalization providing seawater access routes into inland freshwater areas.

For the most part this segment of the GIWW runs to the north of the freshwater line (0.5 ppt), with the exceptions of the Vermilion-West Cote Bays and Lake Salvador near New Orleans. Bay salinity levels vary according to freshwater inflows, with the lowest salinities occurring during the high runoff months of April, May and June. This annual variation is illustrated by Figure V-D for Barataria Bay, which is located due south of New Orleans.

3. Calcasieu River Salt Water Barrier. The Calcasieu salt water barrier project is located at mile 38.7 on the Calcasieu River, four miles upstream from Lake Charles, and 16 miles upstream of the GIWW (see Figure V-E). A deepwater channel from the Gulf to Lake Charles is maintained to a depth of 40 feet and 35 feet from mile 34 to mile 36. The project consists of a closure dam, a floodway control structure, and a navigation sector gate.

The purpose of the barrier is to prevent salt water intrusion upstream where it would interfere with the irrigation of rice lands. During the non-agricultural season, October first to March first, the floodway tainter gates are fully opened, providing essentially natural flow conditions. At the beginning of the agricultural season, March first, the flood gates are operated to control salt water intrusion. Operations personnel consider storm runoff as well as daily tidal fluctuations in the gate opening schedule. The tainter gates are opened to pass vessels, which consist primarily of light traffic of the petroleum and fishery industries. The salinity above anid below the structure is continuously monitored, which provides a continuous appraisal of the daily operating procedures.

In recent years, modifications of the operating plan to allow flushing of irrigation water sources have been as

Figure V-D

Annual Variations in Salinities in Barataria Bay, Louisiana

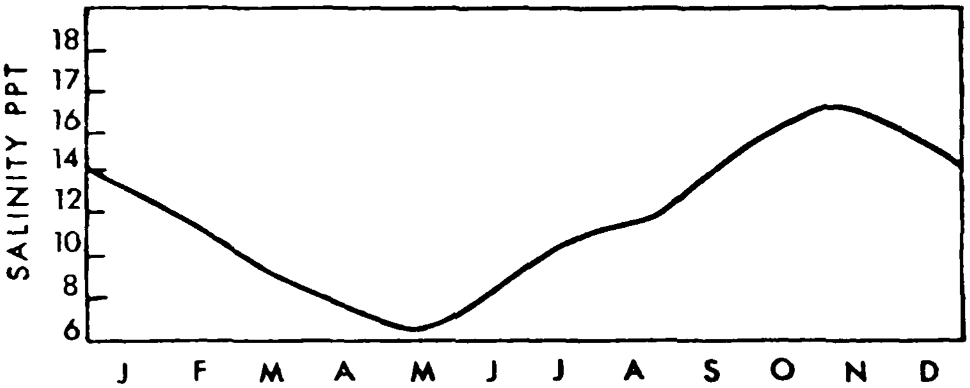
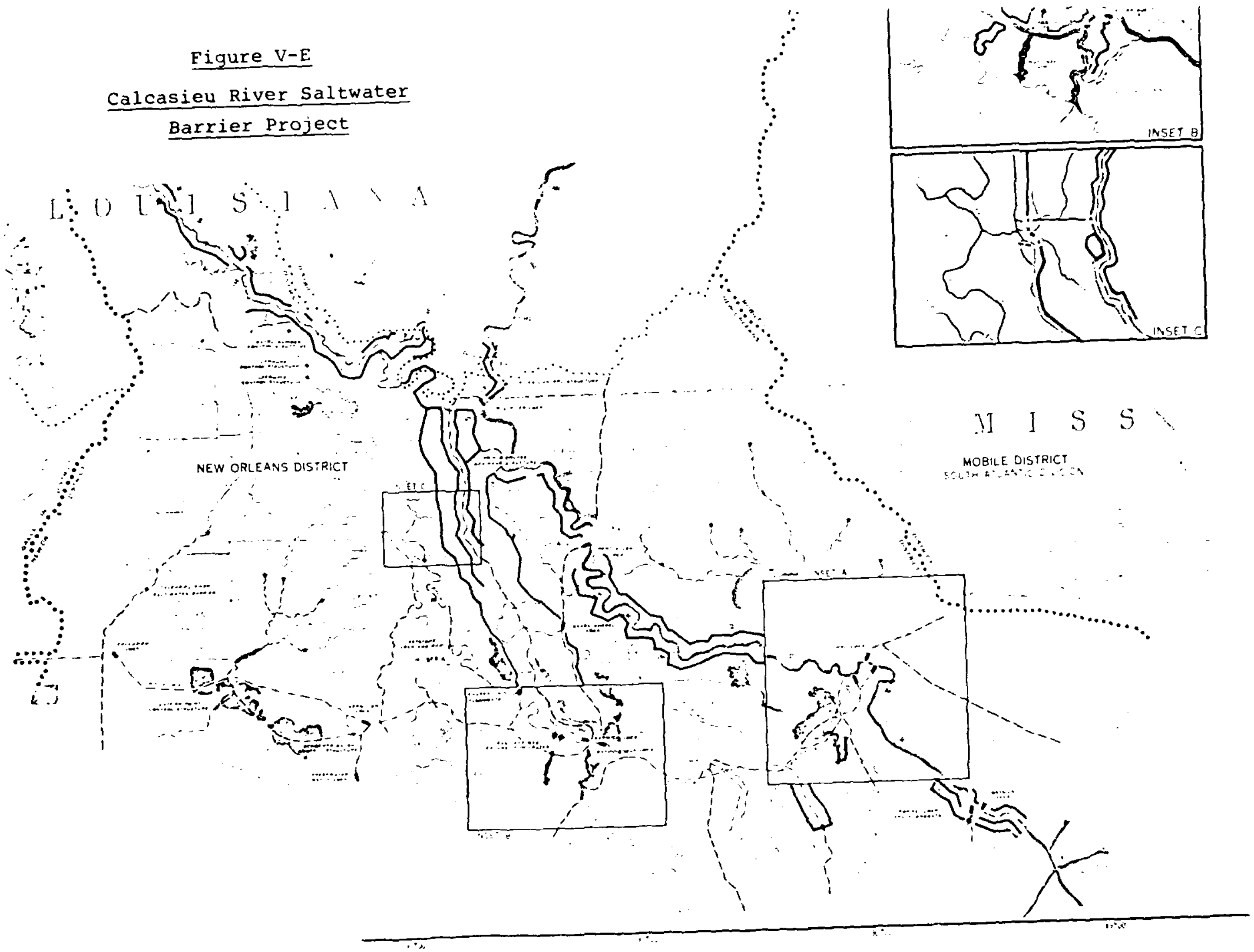


Figure V-E

Calcasieu River Saltwater

Barrier Project



a result of concern by agricultural interests about increasing salinities in the Calcasieu River. Stream flow during the irrigation season is sometimes deficient, while surplus amounts of runoff occur in the preirrigation months. Surplus runoff cannot be stored in the upstream reaches, but may be used to flush or dilute the seawater salinities which penetrate into the upstream reaches. Flushing operations scheduled about one month in advance of the irrigation season have been found to be beneficial. Also, during extreme drought situations, operational procedures now require that the lock chamber be full to capacity for each lockage. This has caused some delays to navigation.

4. Mermentau River Basin. Four other structures in the Mermentau River Basin - Catfish Point Control Structure, Schooner Bayou Control Structure, Calcasieu Lock, and Vermilion Lock - control the impoundment of water for irrigation and prevent salt water intrusion into the Mermentau Basin. As shown in Figure V-E Catfish Point is located on the Mermentau River and is designed to prevent saline water from entering Grand Lake. Similarly, Schooner Bayou prevents saline water from entering White Lake. Both of these structures are opened during high lake levels and vessels are allowed unrestricted passage. The commercial traffic is light, however, consisting primarily of fishing vessels.

The Calcasieu and Vermilion locks were constructed to prevent salt water intrusion into the Mermentau Basin through the GIWW and are operatd in conjunction with the Schooner Bayou and Catfish Control Structures for regulation of the water levels in Grand and White Lakes. This is the only section of the GIWW that is maintained as a freshwater canal.

The general plan of operation for projects in the Mermentau River Basin provides for the conservation of freshwater by maintenance of normal lake stages, the prevention of uncontrolled tidal inflow during the rice irrigation season, flood control during periods of high stages, limiting periods of head differentials different from zero in the interests of navigation, and the periodic operation of the project in the interests of fish and wildlife when not detrimental to other interests.

The effects upon navigation of the operation of Vermilion Lock and Calcasieu Locks as salt water instrusion barriers is to slow the passage of twos traversing the GIWW and the release of local flood waters. An "open pass" condition is said to exist when both gates of a lock are opened. This procedure is used either to pass flood flows or to faciliate the passage of commercial vessels. Open pass conditions at Calcasieum to pass local flood waters are frequent. During these times, navigation through the structures may be hazardous due to the high velocities of flow. Traffic trying to navigate against the current may experience difficulty because of lack of sufficient horsepower, whereas traffic moving with th8e current experiences steering problems. In either case, towboat operators sometimes choose to delay passage through the lock until head differentials decrease. Open pass conditions at Vermilion to pass flood flows are rare, since the antiquated tumbler gates cannot be raised if the head differential exceeds .3 feet.

The open pass lock operation procedure may be initiated at Calcasieu to facilitate passage of commercial traffic during non-crop seasons of the year and when the head differential is sufficient to inhibit salt water intrusion. Because rice, the primary crop grown in the area, is usually irrigated during the months of March through August, open pass conditions are normally avoided during those months. However, during non-crop seasons, open pass may be initiated to "flush out" tow queues at Calcasieu. Open pass is not normally used at Vermilion, due to the gate operation problems and the proximity of the agricultural area of the lock.

Vermilion Lock is presently a hindrance to navigation as its sill depth and width are undersized in comparison with other GIWW locks. It is authorized for replacement with the intitial excavation and approach channels scheduled for award in fiscal year 1980.

A recent EIS on the Mermentau Basin[7] indicated several beneficial and adverse impacts of water control structures. Salinity control structures at Catfish Point and Schooner Bayou, plus locks at Vermilion Bay and Calcasieu River, have reduced salinities in Grand and White Lakes to the point that impounded waters are suitable for irrigation of adjoining rice-growing areas. As a result of the control structures, the normal cycle of estuarine

depe dent organisms, e.g., shrimp and crabs, have been blocked except at certain periods.

As salinity dropped and water levels rose, changes have taken place in the biota of the lakes. Brackish and saline vegetation has been replaced by freshwater species. Previous detrital input into the lower Mermentau River system and Gulf has been lost due to the presence of these structures. High water levels have prevented annual grasses and sedges from growing along shorelines. These plants are favorite native food species for migratory water fowl such as ducks and geese.

Salt water fisheries have all but ceased, with catfish buffalo, freshwater drum, and gars predominating in commercial catches. Largemouth bass, black and white crappie, and several species of sunfish are frequently sought by sportsfishermen. Furbearers, especially nutria and muskrats, have decreased in numbers as a result of higher water levels, inadequate food supplies, and a reduced available habitat.

Lower water levels have pools and small ponds in which small fish are often trapped, providing food for wading birds such as herons, ibises, and egrets. High water levels have reduced this niche significantly. Shoreline erosion rates have been increased due to high water levels. Marked shoreline changes have taken place, as evidenced by maps and charts of the area.

<u>5. Waterway Deepening to Port of New Orleans.</u> The Mississippi River and the Mississippi River - Gulf Outlet (MRGO) currently provide deep draft access to the Ports of New Orleans and Baton Rouge. Present channel dimensions of the MRG are 36 feet deep and 500 feet wide. A study authorized in 1968 has considered providing another separate channel with a minimum depth of 50 feet and a width of 750 feet (COE, 1974). One of the major objections to the channel deepening project is the concern that salt water will be introduced into the water supply of the city of New Orleans.

Lake Pontchartrain , the MRGO channel, and Breton Sound reach their maximum and minimum salinities during periods of low and high freshwater inflow, July through November and March through May, respectively. The Gulf, the sound, the channel and the lake have average maximum

salinities of 34,000, 28,000, 26,000 and 7,700 ppm, respectively.

Before construction of the MRGO, salinities in Lake Pontchartrain varied from an average minimum of 850 ppm to an average maximum of 4,250 ppm. The average surface salinities in ppm in the channel area before and after completion of the channel at Hopedale (mile 38), Paris Road Bridge (mile 61), and Little Woods (on the south shore of Lake Pontchartrain slightly east of the Inner Harbor Navigation (Canal) for the years of 1958 and 1965 are shown in the table below. These data reflect the substantial increases in salinities caused by construction of the MRGO.

Average Surface Salinity, TDS (ppm)

Year	Hopedale	Paris Road Bridge	Little Woods
1958	3,100	1,300	1,300
1965	7,700	5,500	3,000

The increasing salinities in Lake Pontchartrain have had an interesting effect on the fishing industry. As the salinities increased after the construction of the MRGO, so did the salt water fish, especially oysters. The fishing industry in many cases found Lake Pontchartrain to be more attractive than the Gulf, and today any attempt to return the lake to its original freshwater condition would meet with great opposition from the fishing industry.

Salinities in the Mississippi River are functions of discharge. At very low discharges of less than 150,000 cfs the tip of the salt water wedge can be expected to extend to New Orleans.

The channel bottom configuration plays an important role in influencing salt water intrusion. The salt water wedge advanced in the low flow year of 1956 all the way to Keniner, mile 115, where there is a natural sill which has historically provided a barrier to the advance of the wedge. Dredging the channel to a depth of 50 feet would remove the upper part of this sill and allow salt water intrusion to penetrate further upstream.

6. Houma Canal. The Houma Canal provides a direct route between the GIWW and deep water in the Gulf. The canal is a man-made channel 15 feet deep and 150 feet wide which runs from the city of Houma south for 42 miles to the Gulf. Salinities near Houma increased from a yearly average of 113 ppm to 241 ppm after completion of the canal in 1962. Salinities above 250 ppm occur during low flow periods at the Houma water supply station. This has required the city of Houma to utilize Bayou Black as an alternate source of water when salinity concentrations exceed 250 ppm.

In 1964, Bayou Black was made into a reservoir by constructing several dams and control structures. Information available for the years 1971, 1972, and 1973 indicated that pumping was necessary for 155, 97, and 26 days, respectively, to maintain freshwater at Houma. Utilization of Bayou Black is more costly than the Houma Canal because of the added costs of water treatment and pumping[8].

7. Strategies for Control of Salt Water Intrusion. There are several potential strategies, both operational and structural, that could be implemented by the Corps to control salt water intrusion. These strategies include the construction and operation of flow control structures, the alteration of flow regimes to allow freshwater inflow into the estuaries, and the provision of navigating corridors which would concentrate traffic and development along the corridors.

One of the principal objections to the construction and operation of control structures is that they tend to inhibit the free passage of marine organisms which require water of different salinity levels at different stages of their life cycles. Some of these organisms are extremely important to the local fishing industry.

The Corps, in cooperation with the Louisiana Wildlife and Fisheries Organization, has recently begun operating control structures to promote fish passage. The control structures at Catfish Point and Schooner Bayou, for example, are scheduled to be opened during incoming tides for short periods coinciding with peak populations of juvenile marine organisms near these structures, in order to allow passage into the lower Mermentau Basin. The timing of this action is to be determined in part by the monitoring of these organisms by the Wildlife and Fish

Commission. The periods of peak abundance are usually early spring and late summer. Other Corps projects could be operated in the estuarine zone in ways which would give more consideration to marine organisms migrating between freshwater and marine zones.

A second strategy that has been suggested to control salt water intrusion is the diversion of freshwater inflows into specified zones to provide the required water quality. There are a number of freshwater basins to the north of the GIWW, dominated by extensive swamps, marshes, and lakes. They are usually underlain by thick deposits of peat and organic clay, which provide very poor foundation conditions and limit land use. Their value is primarily known to sportsmen and naturalists of the region. These basins are also important as natural reservoirs, ensuring freshwater flow into the estuarine zone south of the GIWW throughout the year.

The freshwater inflow is one of the primary factors in controlling estuarine water quality. Its impact could be enhanced through the provision of canals and control structures. It should be noted, however, that the alteration of these flows through drainage projects, canal dredging, flood control projects, and highway embankments has been one of the major factors in increasing salt water intrusion into the estuaries in the past. Therefore, any action to further change the flow regime would have to be carefully studied to avoid further damage to the estuaries.

An alternative to the use of the swamp lands north of the GIWW would be to divert supplemental water from the Mississippi and Atchafalaya Rivers. This is a potential solution to restore a more favorable balance of saline conditions in the Terrebonne-Barataria areas of south central Louisiana.

Another possible approach to control salt water intrusion effects would be the development of a major regional plan delineating "development corridors." Such corridors would be located in areas that are already heavily developed or where development is projected. Public works projects would be focused on the corridors to strengthen and further define them. Corps projects such as flood protection levees, drainage projects, and navigation canals should be incorporated with other agency activities such as highways, pipelines, power lines, and other

linear elements. Such an approach would reduce the criss-cross development patterns that have characterized navigation channels in certain areas and allow for more control over estuaries by reducing their access points to major channels. Similarly the deepening of minor rivers and bayous along the GIWW could be concentrated as well in development corridors.

Dredging by the oil and gas industry has been a major factor in the creation of canals throughout the Louisiana zone. It is estimated that 25% of the 16.5 square mile average annual net land loss during the past 30 years is the direct result of petroleum industry dredging. During the past few years the Corps has given fewer permits for dredging and has begun to require an environmental impact evaluation. This has served to reduce dredging activities and could be used further to control developments related to salt water intrusion.

8. Conclusions. Along the GIWW the dimensions of natural waterways have been inadequate to meet navigation demands and many have been enlarged. In addition, many canals have been constructed throughout the coastal area. The larger and deeper canals generally provide deep water access to the Gulf of Mexico for marine traffic. The majority of the canals, however, have been constructed to facilitate the exploitation of the vast oil and natural gas resources in the estuarine zone.

These canals have changed the distribution of fresh and salt water along the Gulf Coast. Deepwater outlets to the Gulf of Mexico have also permitted the intrusion of saline Gulf water, raising salinity levels over large areas.

The Corps has constructed and operated salt water intrusion locks and barriers to protect agricultural areas for many years, but has recently required more attention to be directed at environmental concerns. Greater emphasis is now being placed by the Corps and other federal and state agencies on protecting the Louisiana Coastal zone from salt water intrusion.

The potential impacts of salt water intrusion in this segment include its effect upon municipal water supplies and estuarine fishing environments. The water supply of Houma, Louisiana, for example, has received unacceptable levels of saline water because of channel construction.

If the city of New Orleans were to be placed in a similar position due to salt water intrusion from channel deepening, other sources of water supply would be required. This would be a very costly endeavor given the water requirements for populations the size of New Orleans.

Salinity changes in Lake Pontchartrain and other estuarine areas in coastal Louisiana are examples of impacts of channel construction upon the fishing industry. The salinity changes have created new preferred habitats for shellfish and other fish populations. In the past fishing industry has simply moved to new locations, but any future changes in fishing industry has simply moved to new locations, but any future changes in fishing conditions will be resisted by the fishing industry. Navigation projects which affect estuarine fishing conditions may require mitigation in the form of the provision of suitable environments for new fishing grounds.

Presently Corps projects concerning navigation do not appear to be affected by the salt water intrusion issue, although drought conditions and reduced flow because of consumptive uses could pose future problems due to greater upstream movements of the salt water wedge. However, future projects are being carefully investigated for potential changes in salinity conditions imposed by the project. Since the Louisiana coastal zone is very sensitive to even minor alterations of its marsh environment, this may well preclude future projects or at least require extensive mitigation measures before project authorization is granted.

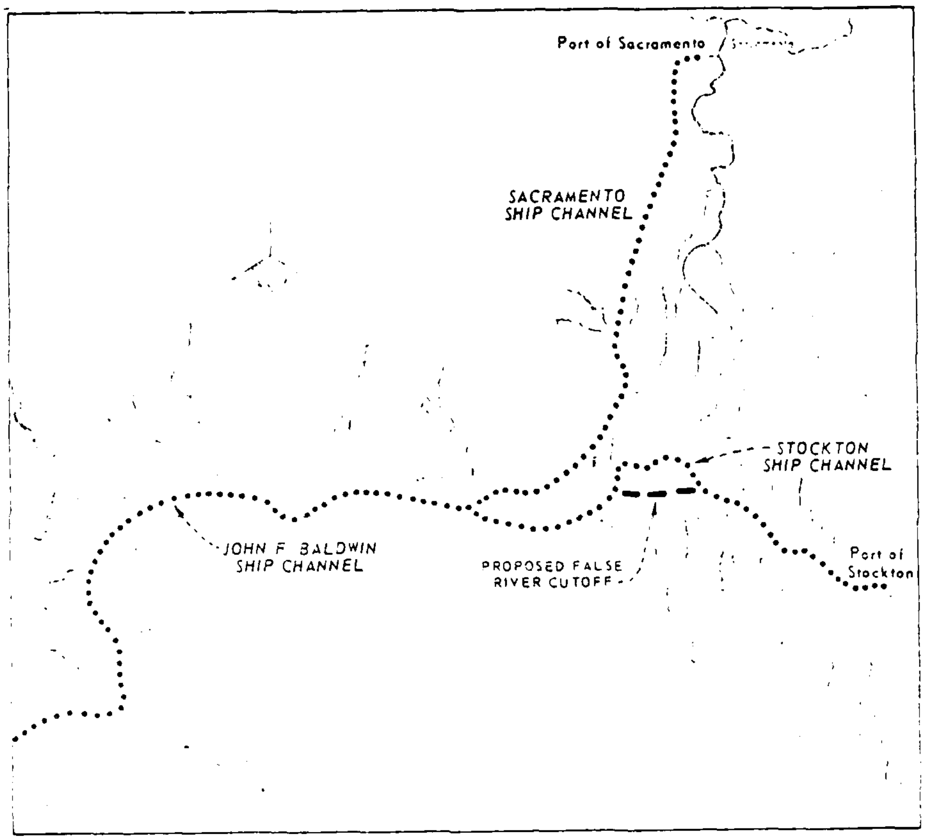
(c) San Francisco Bay*

1. Environmental Description. The San Francisco Bay/Delta system is fed by the Sacramento and San Joaquin Rivers. The drainage area covers 59,000 square miles in Central California. The lowest portion of the valley floor is known as the Sacramento-San Joaquin Delta, generally described as the area between the cities of Sacramento, Stockton, Tracy, and Antioch (see Figure V-F). The

*This section is based on preliminary data supplied by the Corps of Engineers. By the time this report is published more recent information will be available.

Figure V-F

Sacramento-San Joaquin Delta



Delta ranges in elevation from 18 feet to 20 feet below sea level and covers an area of 740,000 acres. This area includes 440,000 acres of reclaimed lands, 50,000 acres of water surface, and 700 miles of waterways. During the last century, levees have been constructed along the waterways to divide the Delta into about 60 separate parcels which have been drained to form islands. The waterways provide habitat for a varied fishery and are used for both recreational boating and commercial navigation.

Most of the water from the 64,000 square mile Central Valley watershed, or roughly one-third of the entire State of California, drains through the Delta, and most of this water originates as run-off from winter rains in the valley and foothills and from spring tributary to the Delta, produces eighty percent of the total runoff. Large-scale diversions and federal and state, and local water projects constructed within the watershed in the past have cut the mean annual outflow from the Delta by agricultural pumping, vegetative transpiration, and by the Constra Costa Canal, South Bay Aqueduct, California Aqueduct, and Delta-Mendota Canal.

Lands of the Delta are presently used primarily for agricultural purposes. Corn and small grains are the dominant crops, but considerable land is used for orchards, vegetable production, and grazing. Much of the land is irrigated by pumping or syphoning from the canals over the levee system and onto the lower lying agricultural fields. All of the agricultural fields are reclaimed lands that depend upon the levee system for their protection.

The Delta is one of the most important areas for fisheries in California. It is used by anadromous as well as by resident species. Anadromous fish using the study area as a spawning and nursery ground include Striped Bass, King Salmon, American Shad, Steelhead, and White and Green Sturgeon.

Wildlife species inhabiting the study area are diverse and abundant. Important avian species include wading birds, shore birds, waterfowl, upland game birds, and over 150 non-game species. Mammalian species include beaver, mink, muskrat, river otter, skunks, raccon, and other small rodents. Upland game species such as pheasant quail, dove, and cottontail rabbit are abundant in the study area. The Suisun Marsh provides habitat for the

majority of the wildlife found throughout the Delta, but the marsh is particularly attractive to wintering waterfowl of the Pacific Flyway.

2. Commercial Navigation and Corps Projects. Commercial navigation within the Delta is accomplished through the Sacramento and Stockton Deep Water Ship Channels. The Stockton Channel became operational in 1933. It follows the natural course of the San Joaquin River with a channel depth of 30 feet. The Sacramento Channel is a slack water channel which was constructed alongside the Sacramento River. Recreational boating is extensive throughout the Delta. The ship channels are shown in Figure V-F.

Presently, commercial traffic consists of boith shallow and deep vessels which transport primarily petroleum and farm produce. Most of the deep draft vessels calling at the Ports of Sacramento and Stockton arrive empty and are only partially loaded because of channel depth considerations. Normally the ships then proceed to the Oakland or San Francisco ports where they are topped off. The Corps has received authorization for channel deepening of both the Stockton and Sacramento channels. At the present time a draft feasibility report and EIS has been completed for the Sacramento Channel and a revised draft GDM has been completed for the Stockton Channel (COE, 1979).

3. Salt Water Intrusion. Historically, the Sacramento and San Joaquin Rivers have long been diverted for agricultural and other purposes, beginning in the 1850s. Such diversions had the effect of modifying and generally decreasing flows. Storage projects, particularly large ones carried out since 1940, have tended to counteract the impact of diversion projects by augmenting dry season flows through reservoir releases.

Salt water intrusion into the Delta is a function of fresh water flow conditions out of the Delta. Under previously existing natural conditions, the fall low flow season and periodic droughts caused considerable movement of the saline interface. Return flows from ever-increasing acreages of irrigated farmland in the Central Valley and the Delta have also contributed top salinity problems in the Delta by carrying with them salts leached from agricultural soils.

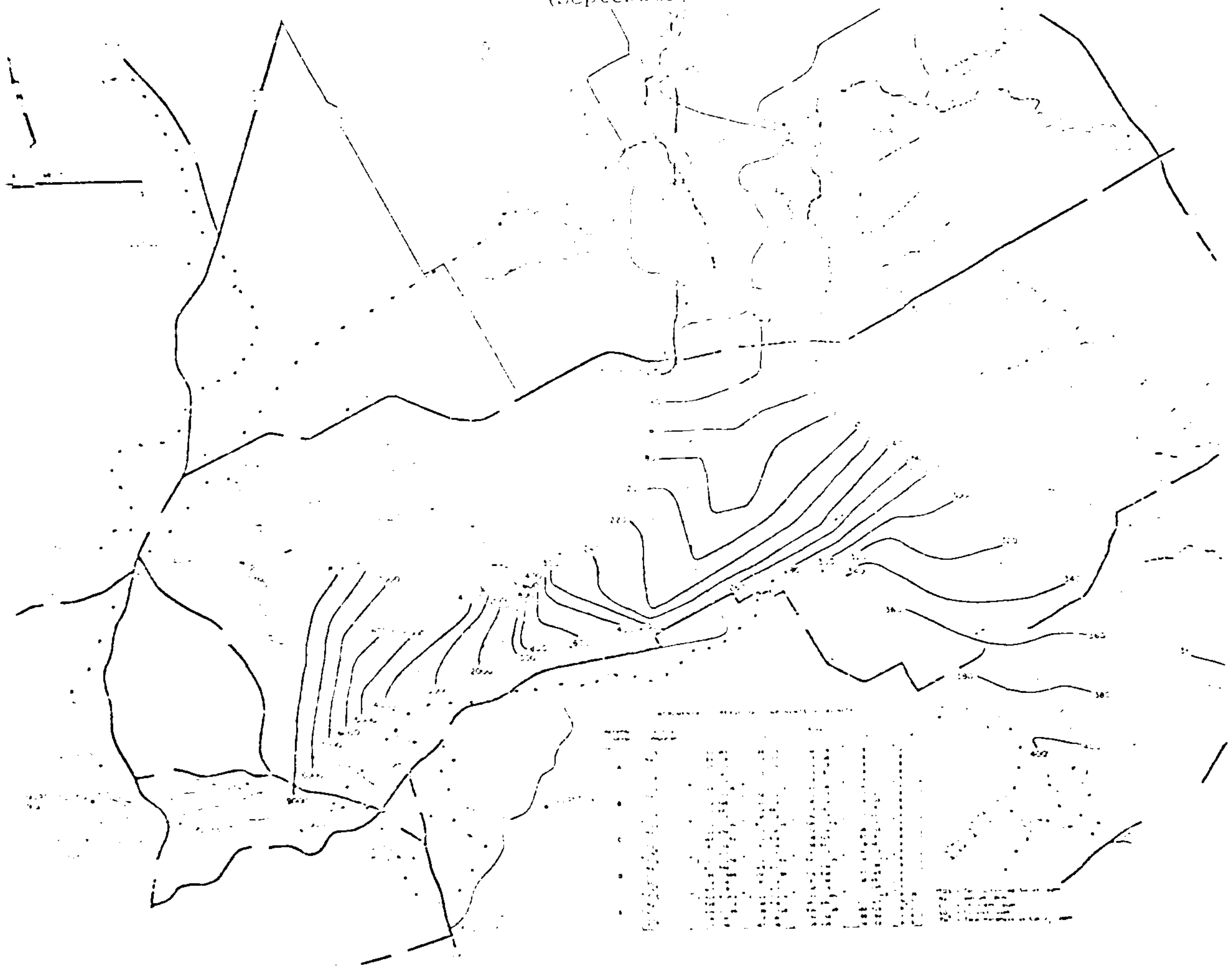
Presently, the salinity conditions in the Delta are influenced by a number of factors. Natural factors include drought conditions and the resultant extended periods of low outflow. Upstream diversion and storage projects continue to exert a major influence on salt water intrusion. Within the Delta, projects that are presently operating to influence salinity levels include the previously mentioned state and federal water export projects, which affect Delta outflow and flow distribution within the Delta, and ship channel and levee projects, which affect the tidal contact and flow distribution.

As an indication of the actual salinity values and their seasonal fluctuation in the Delta, two representative months are presented. A high runoff month, January, is shown in Figure V-G Salinity (TDS) was found to be moderate (900 ppm) at the western edge of the Delta and decreased upstream until the acceptable limit of salinity (500 ppm) was reached just below the entrance to the Sacramento Canal. Salinity values elsewhere in the Delta were all of acceptable quality (below 500 ppm TDS). The low inflow month of September is shown in Figure V-H. Salinity values at Carquinex Strait were 16,000 ppm and the freshwater limit of 500 ppm moved upstream 11 miles to the area near Jersey Island. Isolated bays on the eastern edge of the Delta, where stream flows are low, exhibited high salinities. Both the Stockton and Sacramento Channels were found to have TDS values below 200 ppm at all times of the year, although somewhat increased salinities were reported at the ports themselves because of ballast discharges. The ballast discharges result from the need for ships which are not carrying cargo to maintain a weight distribution which is favorable to navigation. Normally ballast is provided by pumping seawater into the ships and then discharging it while the ships are being loaded.

One point of high concern is the proximity of the 500 ppm salinity levels to the Contra Costa Canal at Rock Slough (see Figure V-G.) This canal supplies water to many municipal and industrial water users within the Delta. Several municipal water suppliers in Contra Costa County pump directly from the river when water quality permits and then divert from the canal the rest of the year. Any significant increases in river salinity could require these purveyors to rely exclusively on the canal as a water source.

Figure V-G
Salinity Values: Seasonal Fluctuations

Figure V-H
Salinity Values: Low Inflow Month
(September)



Recognizing that the operations of upstream storage and Delta export projects will largely determine the levels of salt water intrusion into the Delta, the State Legislature has directed in 1959 that water not be diverted from the Delta for use elsewhere unless adequate supplies for the Delta are first provided. The State Water Resources Control Board has issued several decisions which bear directly on salinity condition in the Delta. The "Delta Decision 1379," issued in 1971, established water quality standards for agricultural, municipal, and industrial uses and for the protection of fish and wildlife. Other decisions established minimum flows and release requirements for upstream reservoirs. In 1975, the Central Valley Regional Water Quality Control Board adopted a Basin Plan which included water quality objectives for the navigation channels. Intermittent water quality data collected between 1963 and 1972 indicated that, except for salinity, the water quality in the channel meets or exceeds the objectives.

The Bureau of Reclamation (USBR) has previously held that the State of California decisions on water quality and minimum stream flows, insofar as they restrict the operation of federal projects, are not binding on USBR projects. Litigation resulted in a 1978 Supreme Court decision which held that the Bureau must comply with conditions in state water rights permits that are not in conflict with congressional directives authorizing federal projects. While the final decision of the Court has not been made, it appears clear that water quality control in the Delta must meet the state established standards. These standards may be modified and reestablished periodically. However, in the future it appears probable that federal and state projects will be operated in a manner which gives more consideration to water quality goals in the Delta.

4. Stockton and Sacramento Channel Deepening. Extensive tests and modeling have been conducted to determine the effect on salt water intrusion of the proposed deepening of the Stockton and Sacramento Ship Channels. Initial model tests of the Stockton Ship Channel were conducted with the San Francisco Bay-Delta Model between 1973 and 1975. These tests showed a slight increase in salinity concentrations at several locations in the Delta was a result of deepening the Stockton Ship Channel and constructing the False River Cutoff. Tests of deepening both the Sacramento River Deep Water Ship Channel and the

Stockton Ship Channel were also conducted in 1975. These showed a slightly higher increase in salinity at certain stations than did the Stockton Channel alone. The existing and proposed channel dimensions are shown in Table V-1.

During review of the draft EIS by interested agencies and organizations, many concerns were raised about the slight increases in salinity caused by the channel deepening and realignment. Another concern was expressed regarding the combined effect of the channel deepening and the state's proposed Peripheral Canal* on salinity distributions. It was therefore decided to reexamine the project effects on water quality in more detail.

Several realted studies were conducted by the Corps and Corps contractors in 1977 and 1978. Also during this period, tests were conducted with the Bay-Delta Model to determine 1) the effects on salinity of deepening the Sacramento and Stockton Ship Channels and 2) the effects of installing a submerged sill in Carquinez Strait. The originally proposed False River cutoff was eliminated from the plan as a result of these model tests, which showed that this part of the proposed project could have a significant impact on salt water intrusion in the Delta.

These tests showed that changes in salinity due to deepening the Stockton Ship Channel without the False River cutoff combined with deepening of the Sacramento River Deep Water Ship Channel to 35 feet are smaller than the model can accurately predict (COE, 1979). The tests also show that including the submerged sill would reduce salinities to below pre-project conditions at many locations in Suisun Bay and the Delta. The location and the salinity values are shown on the accompanying Figure V-A and Table V-2. The tests and studies of the submerged sill show that with a tidal flow of 500,000 cfs there would be a small 1-2.5 foot per second local increase in velocities at flood and ebb tide in the velocity of the sill. Tidal stages would not be affected under normal conditions. They would be increased by a maximum of 0.4 feet in the remainder of the Delta during extreme flood

*The Peripheral Canal would divert water from the Sacramento River and route it around the easterly side of the Delta for an ultimate destination in the California aqueduct for delivery to the San Joaquin Valley.

Table V-1

Existing and Proposed Channel Dimensions

Existing and Proposed Channel Dimensions in Feet

Channel	Existing Dimensions		Authorized Plan-D		Proposed Plan-H	
	Bottom Width	Depth	Bottom Width	Depth	Bottom Width	Depth
STOCKTON SHIP CHANNEL						
Golden Gate to Avon	600	35	600	35	600	35
Avon to Middle Point	300	30	600	35	600	35
Middle Point to Pittsburg	300	30	400	35	400	35
Pittsburg to Antioch (New York Slough)	400	30	400	35	400	35
Antioch to Prisoners Point	400	30	400	35	400	35
Prisoners Point to Stockton	225	30	225	35	225	35
SACRAMENTO RIVER DEEP WATER SHIP CHANNEL						
New York Slough (Pittsburg) to Junction Point (SRDWSC mile 15.0)	300	30	300	30	400	15
Junction Point to Manmade Channel (mile 18.6)	300	30	300	30	300	35
Channel mile 18.6 to Sacramento	200	30	200	30	250	35

conditions. It was also concluded that sediment deposition would not be affected by the sill. Biological studies have shown that the sill would have no effect on phytoplankton concentrations and dissolved oxygen.

On the basis of model test results and related studies, the Corps concluded that deepening the Stockton Ship Channel to 35 feet would have no effect on salinity distributions or concentrations in the estuary. This conclusion differs from earlier findings of a slight increase in salinity concentrations, due to the elimination of the False River Cutoff from the plan. Furthermore, deepening of the Sacramento River Deepwater Ship Channel would also have no measurable impact on salinities in the estuary.

Model and related tests show that construction of the submerged sill in Carquinez Strait would reduce salinities to below pre-project levels at several locations in Suisan Bay and the Delta. These locations are generally in the area near the confluence of the Sacramento and San Joaquin Rivers. Construction of the sill would cause no change in sediment transport, tidal stages, or velocities (except near the sill) and would not affect navigation. Consequently, there would be no long-term changes in the estuary as a result of constructing the projects, wither with or without the sill.

A pre- and post-project salinity monitoring program has been proposed to verify that deepening the Stockton and Sacramento Channels will cause no significant adverse changes in the estuary. If a significant adverse change in salinities is determined to follow the deepening, the submerged sill could be constructed in Carquinez Strait. Monitoring would then continue after sill construction to determine its effectiveness.

Separate tests were carried out to evaluate the possibility of salt water intrusion into groundwater. Test-hole data indicated that no fresh water aquifers would be exposed as a result of deepening the channel. However, a monitoring program has been proposed to monitor the groundwater quality both during and after construction.

The studies state the possibility of decreasing dissolved oxygen concentrations in the San Joaquin River. The Corps has included mitigation measures if the project does cause a decrease in water quality because of lowered DO. No other mitigation measures are proposed.

It is expected that fish and wildlife interests will continue to question the project, primarily because of an uncertainty in regard to the project's effect upon phytoplankton growth and DO concentration. Sediment transport will be changed somewhat by the project. Phytoplankton growth is particularly sensitive to suspended solids and their effect upon light penetration.

5. Strategies for Control of Salt Water Intrusion. There have been several strategies and projects proposed to control salt water intrusion in the Bay/Delta area from all sources. An Interagency Committee composed of state and federal representatives has proposed four possible measures[10]. The proposals are termed 1) Hydraulic Barrier, 2) Physical Barrier, 3) Data Waterway Control, and 4) Peripheral Canal.

The Hydraulic Barrier concept provides for the construction of upstream reservoirs with storage volumes allocated for release during low flows to dilute the saline inflow. A major concern with this proposal is the lack of available water, as much of California's water is already overallocated. It would also be the most costly of the four plans.

The Physical Barrier was designed for construction at Chips Island. It would consist of a dam, navigation lock, and fish passage facilities. Freshwater releases to the ocean would largely be limited to those required for navigation. Of the four plans this would assure the best quality of water.

The Delta Waterway Control plan provides for the construction of control structures to maintain a separation between the Delta and export water. Controlled releases would be made through many of the channel gates to meet local water requirements, to achieve environmental control, and for fish and wildlife needs. Further controlled outflows would be permitted to control salt water intrusion. An irrigation distribution system would be included for the western Delta lowlands.

The Peripheral Canal would divert water from the Sacramento River at Hood and route it around the easterly side of the Delta. The water would then be pumped for delivery into the San Joaquin Valley and southern California system. Releases would be made at several locations to meet the needs of the Delta and to protect it

from salt water intrusion. This plan was deemed to be the best for the fish and wildflie of the Delta and was considered to be the most desirable by the Interagency Committee. The authority exists within the State Department of Water Resources to construct the Canal. However, no construction program has been established.

There are several other projects in addition to the projects considered by the Interagency Committee which could exert an impact on Delta salinity. These projects include the construction of upstream reservoirs, master drains, Delta levees, and ballast tanks.

Major reservoirs already exist on many important rivers in the Central Valley. Two reservoirs are under construction, Auburn Reservoir on the American River and New Melones Reservoir on the Stanislaus River, and five other reservoirs are authorized for construction by federal agencies.

Another possible project which would affect freshwater flows is the proposed San Joaquin Mastern Drain. The purpose of the drain is to deliver saline wastewater flows from irrigation in the San Joaquin Valley to the lower Delta. This project is being considered by the USBR and the State Department of Water Resources. One drain, the San Luis drain, which will improve salinity conditions in the San Joaquin River, is already under construction by the USBR. Another viable alternative which has been suggested for agricultural return flows includes the use of this water for power plant cooling. The final disposal would be evaporation ponds.

Ballast tanks or evaporation ponds are possible solutions to high saline concentrations around ports. The tanks would receive effluent from ships and then dispose of the saline waters either through evaporation or by returning it to the waterway during periods of adequate flow. Sacramento harbor, in particular, has reported high salinities from ship ballast discharges.

6. Conclusions. The freshwater supply to the Delta has been steadily decreasing. Withdrawals in the Delta and export from the Delta of water for agriculture, municipal, and industrial uses are steadily increasing. Most of this water is diverted from the Delta via the Contra Costa Canal, the Delta-Mendota Canal, the South Bay Aqueduct, and the California Aqueduct. Return flows to

the Delta, especially from agricultural areas, are high in salt concentrations. Within the State of California and the Delta, in particular, there is an increased demand to maintain water quality. Environmental groups have advocated strict controls to protect the Delta, including federal legislation. These factors require waterway users to assess their legitimate claims to waters and their expected strategies in the event oif a drought or low flow condition.

Several strategy components, both structural and operational, offer possible solutions to controlling salt water intrusion in the Delta. Structural solutions include constructon of upstream reservoirs, a dam and navigation lock in the lower Delta, the Peripheral Canal, master drains, and the submerged sill. The dam and navigation lock is not considered necessary unless there is a significant degradation beyond present salinity levels. The submerged sill is included in present plans, to be constructed if the channel deepening projects ultimately cause increases in salinity. The other structural solutions are outside the Corps' sphere of activities and are being considered by other federal and state agencies.

One other possible structural solution to control high salinities around ports would be the construction of ballast tanks or evaporation ponds. Although the Port of Pittsburgh utilizes ballast tanks in the lower Delta, there are no plans at the present time to construct ballast tanks at Sacramento or Stockton, as the salinities there are not considered significant. Projected traffic levels for the future could, however produce significant salinity levels.

Operational strategies that could potentially be implemented by the Corps include provision for releases from upstream reservoirs. The releases would be made in accordance with Delta low flow conditions to lower salinity through the addition of freshwater. In most cases this could only be accomplishd at the expense of other water users and such actions would be controversial. Presently there are no Corps plans for such action.

Competition for water in the Delta is intense and can be expected to increase in the future. Concern over the salt water intrusion effects of proposed channel deepenings has delayed the projects until adequate model

testing could be completed. Model tests show that presently proposed projects will have significant effects on salinity in the San Francisco Bay/Delta if the proposed John F. Baldwin Ship Channel were improved in its entirety. Mitigative control of salt water intrusion could be provided by the provision of a submerged sil.

Salt water intrusion in San Francisco Bay occurs as a result of a combination of activities and conditions which are only partially influenced by Corps activities. It is therefore necessary that the Corps continue to advise and coordinate with other water users to examine the effects of their possible actions on salt water intrusion. Coordinated cooperation among those agencies who have control over waters flowing through the Delta, users of that water, and entities whose activities can affect the water quality is the only long term solution to the control of salt water intrusion.

CONCLUSIONS

Salt water intrusion and its effects upon navigation have been investigated on three waterway segments - the Chesapeake and Delaware Bays, the GIWW West I, and the San Francisco Bay.

The Chesapeake and Delaware Bays appear to have few effects due to salt water intrusion up to the present time, but projected consumptive withdrawals of both surface and groundwater have caused concern. The municipal water supply of the City of Philadelphia, for example, is considerered to be vulnerable to salt water intrusion in the event of drought and/or decreased stream flows. There is also concern that long-term changes from reduced freshwater flow or changes in channel dimensions would cause fish movements to new locations which could have impact upon the fishing industry in the Bay. The effect of increased withdrawals is the subject of several on-going studies but no conclusive results have as yet been reached.

The San Francisco Bay and Delta have been subjected to steadily decreasing stream flows because of water export projects. Also it receives a larger share of drainage from agricultural areas which are high in salt concentrations. Conflicts between water user's including state,

federal, and interstate organizations, have resulted in legislation which has established the state's right to maintain water quality in the Delta.

Deepening projects for the Sacramento and San Joaquin Canal have been modeled and the results show that the projects will not affect salinity conditions significantly in the Delta. However, a monitoring program has been established and if the channel deepening does cause salt water intrusion, then project plans propose a submerged sill to control the intrusion. Other possible solutions to control salt water intrusion include a peripheral canal, master drains, and upstream reservoirs with storage volumes established for low flow augmentation. Any long-term approach to maintaining water quality in the Delta, as in other areas subject to salt water intrusion, will require cooperation among all water users.

In general, it appears that navigation projects, and particularly channel deepening, could have the potential to significantly increase salt water intrusion. However, if adequate mitigation measures are designed into the project, the effects may be reduced to acceptable levels. A monitoring program such as has been established in the San Francisco Bay/Delta will provide solid evidence of the actual effects. Projects will have to be examined on a case-by-case basis for their potential effects.

Along the GIWW the Corps has constructed and operated a variety of facilities aimed at controlling salt water intrusion for many years. In the future, the impacts of channel construction and maintenance upon the environment and man will be given even more importance. As a result, there may be significant restrictions on project construction or extensve mitigative measures may be required.

VI - RECREATION-NAVIGATION INTERACTIONS

This section summarizes the results of the analysis undertaken to identify significant interactions between recreational use of the commercial waterway system and commercial navigation. This analysis is intended to cover all segments where recreation is presently significant. A second part of the analysis is the determination of sites where recreation-navigation interactions are likely to be significant in the future and the forecasting of future recreational demand levels for these sites.

METHODOLOGY

The methodology employed in this analysis began with a review of the available data concerning present patterns of recreation on the waterway system and the extent to which they either conflict with or complement commercial navigation use. A set of segments was then selected for detailed case study and a comparative analysis of the case studies was conducted to establish a framework for the forecasting of future recreation-navigation interactions. Corps data on current recreational use levels were compiled by segment and combined with various conflict indicators in order to establish a list of segments and facilities where recreation-navigation interactions may be significant in the future. Finally, future recreational use patterns were forecast in detail for the selected segments.

(a) Review of Available Data

The analysis began with a review of the available data sources to determine (1) what information is currently available concerning recreational use of the commercial waterways system, and (2) what recreation-navigation interactions are currently seen as significant. Both Corps and non-Corps sources were consulted. The following data sources were used:

1. Documents and interviews provided by Corps personnel.

2. State comprehensive outdoor recreation plans.

3. United States Coast Guard accident data.

4. River basin commission reports and interviews.

5. Interviews with representatives of other interested agencies and organizations, including:

(a) Heritage, Conservation and Recreation Service (formerly the Bureau of Outdoor Recreation), Department of the Interior.

(b) Fish and Wildlife Service, Department of the Interior.

(c) Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, Department of Commerce.

(d) American Boat Owners Association.

(e) Boating Industry Association.

(f) Sierra Club.

6. A general review of recreation literature, with a focus on water-based or water-enhanced recreation.

7. Data contained in the NWS Inventory established for this study by Corps personnel.

8. Data contained in the Corps' Recreation Research Management System (RRMS).

A panel of experts was also consulted to identify potential technological changes in waterway use and how these might affect future recreation-navigation interactions.

Based on this review, it was decided that, on the whole, the Corps' own data systems provided the best available basis for analyzing current recreational use on the commercial waterways system. These data were then collated by analysis segment, and criteria were established for identifying high levels of recreation use by segment, using a number of different indicators drawn from the Corps' own data system.

The range of significant recreation-navigation interactions was identified primarily through interviews with Corps personnel at the Division level. Both conflicts and complementary uses were identified through these interviews. Interviews with non-Corps sources and a review of the recreation literature added little to the range identified through Corps sources, though they sometimes provided additional examples of interactions already identified.

(b) Comparative Analysis of Case studies

In order to better understand the factors involved in present conflict situations, a set of segments was selected for detailed case study. The universe from which this set was selected consists of all segments currently experiencing recreation-navigation conflicts according to one of two criteria. Either the segment was identified in the Corps interviews as a conflict segment, or it had a high level of accidents involving both commercial and recreational craft (five or more over a two year period) according to United States Coast Guard data. Twenty-three segments met one or the other of these criteria. Of these, three met both criteria and were automatically included in the sample selection for the case studies.

A total of nine segments was selected to represent the full range of interactions identified. The distribution of key sample characteristics (authorized and actual use, flow characteristics, and level of commercial navigation) was checked against the distribution for all identified conflict segments and for the full set of segments on the waterway system in order to insure that the sample would be representative.

The following set of segments was selected for case study:

1. Upper Mississippi (lock and dam conflict between commercial and recreational craft, high accident levels).

2. Lower Upper Mississippi (lock and dam conflict between commercial and recreational craft).

3. Lower Ohio-Three (recreational use conflicts with port and fleeting activities).

4. Arkansas (fishing vs. fleeting in oxbow lakes).

5. Florida/Georgia Coast (coastal zone management, dredging and beach creation, high accident levels).

6. Chesapeake and Delaware Bays (port and harbor conflicts, high accident levels).

7. Lake Superior (port and harbor conflicts, potential impact of variation in lake levels).

8. Upper Columbia/Snake Waterway (fishing and boating vs. commercial traffic, conflict at locks and dams).

9. San Francisco Bay (port and harbor conflicts, high accident levels).

In addition to these nine segments, five special studies were conducted. Two focused on the impact of variation in lake levels on reservoir recreation, at Tygart Reservoir on the Monongahela (Segment 16 and at Buford Reservoir on the Chattahoochee Segment 38). A third study conccerned the process of planning for waterways development, with a focus on trade-offs between recreational and commercial uses. This study was based on Segment 37, the Tennessee-Tombigbee Waterway.

A special study of accident data was undertaken for Segment 56, Central/Southern California, the segment reporting the highest number of accidents involving both recreational and commercial craft. Finally, a field trip taken for the multipurpose use study yielded additional data concerning conflicts with recreational craft and shoreline land uses on Segments 11 and 16, the Upper Ohio and Monongahela Rivers.

A systematic framework was established for case study data collection in order to provide the basis for later comparative analysis. Data were collected on the characteristics of the segment under study (location, length, type, authorized and actual uses, facilities, patterns of recreational use, and patterns of commercial navigation). Data were also collected on the characteristics of the socioeconomic environment (land use, population patterns, employment and income).

Each case study focused on one specific major conflict between commercial navigation and recreational use. In addition, attention was paid to secondary recreation/navigation conflicts and conflicts with other uses (hydropower, irrigation, etc.). Special attention was given to identifying beneficial interactions or complementary uses, in order to balance the conflict orientation of the case studies.

The major conflict which was the focus for each case study was described in terms of location, physical parameters (harbor area, lock capacity, channel configuration, water quality, etc.), recreation activities and navigation activities involved, and the preceptions of major participants regarding the causes of conflict.

After the case studies were completed, a comparative analysis was conducted to determine what features of these conflict situations and complementary uses should be incorporated into a model for predicting future recreation/navigation interactions. A conceptual framework was developed to identify potential impacts, based on interactions between three classes of commercial navigation activity and four types of recreation activity.

One of the first conclusions of the comparative analysis was that the analytic segment is not, in itself, an appropriate unit for forecasting recreation/navigation interactions. Significant interactions occur in specific settings which create the conditions under which conflict may occur. For purposes of this analysis, therefore, it

was decided to disaggregate the segments according to six types of settings:

- Lock and dams.
- Pools and channels.
- Port and harbors.
- Reservoirs.
- Free-flowing rivers.
- Lakes and bays.

The first four settings represent waterways facilities, constructed, operated, and maintained to serve the needs of commercial navigation. The latter two are natural settings found on the waterways system but not subject to significant controlling activities by the Corps.

Recreation/navigation interactions generally involve conflict between specific recreational activities and specific navigation activities in a particular setting. From the comparative analysis of case studies, it appeared that four major categories of recreational activity should be treated. These include:

- Boating and water skiing.
- Fishing.
- Swimming.
- Shore-based recreational uses.

The categories of navigation activity which impinge upon recreation uses were identified as follows:

- Planning and design of facilities.
- Operation and maintenance of facilities.

- Commercial navigation activities, including:
  (a) Traffic levels.
  (b) Fleeting variety.
  (c) Port activities.

Certain planning lessons cut across the range of facility types and need to be addressed on a systemwide basis. The results do not lend themselves to a segment-by-segment analysis but are rather appropriate to the institutional analysis of the waterways development planning process as a whole. Other design issues, particularly those pertinent to the location and capacity of facilities, can be addressed at a segment-specific level and directed toward the mitigation of present or potential conflict situations.

(c) Selection of Significant Segments

Corps data on current recreational use of the waterways system were compiled by analytic segment. Four data sources were used: (1) recreational user-days by facility as reported in the Corps Recreational Resource Management System (RRMS) for 1977; (2) Recreational user-days by subsegment as reported in the NWS inventory; (3) recreational craft passing through locks; and (4) recreational facilities as major ports and harbors, including marinas, slips, and launching facilities. A system-wide summary of the data is given in Appendix B.

After reviewing the range of the available data, a number of criteria were set to establish "high levels of current recreational use. These criteria included:

1. Recreational activity accounting for a million or more user-days, according to data in either the RRMS or the RWS Inventory data system. This criterion was applied at the segment level.

2. Recreational use of specific Corps facilities exceeding 500,000 user days, according to RRMS data. This criterion was applied at the facility level.

3. Recreational use of locks exceeding 3,650 craft annually or an average of 10 per day. This criterion was applied to each individual lock.

4. More than ten commercial port containing recreational facilities on the segment. This criterion was applied at the segment level.

5. More than 5,000 total slips for recreational craft in commercial harbors on the segment. This criterion was applied at the segment level.

It was decided that the criteria for establishing which segment would be significant in terms of future recreation-navigation interactions should include three factors:

- High recreation use.
- High navigation use.
- Present conflicts of complementary uses.

The five indicators of high recreation use described above were combined with measures of navigation use and conflict or complementary use, as shown in Table VI-1. Only one measure of navigation activity was used: the level of activity defined for the segment in the NWS Inventory (high use = over 20 million tons annually). Two measures of conflict or complementary use were included: identification by Corps personnel as conflict or complementary use segments, and reported high levels of accidents involving both recreational and commercial craft.

The application of these criteria led to the classification of all waterway segments into four groups, as shown in Table IV-2.

Table VI-1

Waterway Segments Summary of Current and Conflicting Uses

	Segment	Identified by Corps conflict segment	Identified by Corps as complementary segment	5 or more recreation-commercial accidents	High navigation use (20 million tons or more)	Over 1,000,000 annual user days (HWS/RRMS)	Facilities with over 500,000 users days	Locks and dams with recreation use (more than 3,650 craft per year)	High number of recreation ports (more than 10)	High number of slips recreation craft (more than 5,000)
1	Upper Miss.	x	x	x	x	x	x	x		
2	*Lower U. Miss.*	x	x		x	x	x	x		
3	Middle Miss.		x		x					
4	Lower M. Miss.		x		x					
5	Upper L. Miss.		x		x					
6	Lower Miss.		x		x					
7	Miss. (BR)		x		x					
8	Miss. (NO)		x		x					
9	Illinois			x	x	x		x		
10	Missouri			x	x	x	x			
11	Upper Ohio		x		x	x				
12	Middle Ohio		x		x	x	x			
13	Lower Ohio I	x	x		x					
14	Lower Ohio II		x		x					
15	Lower Ohio III		x		x					
16	Monongahela					x	x			
17	Allegheny							x		
18	Kanawha									
19	Kentucky									
20	Green									
21	Cumberland					x	x			
22	Upper Tenn.					x				
23	Lower Tenn.					x				
24	Arkansas	x	x			x	x			
25	Ouachita					x	x			
26	Old & Atchafalaya				x					
27	Baton Rouge Bypass				x					
28	GIWW W (E)				x					
29	GIWW W (M)							x		
30	GIWW W (S)									
31	GIWW E (W)				x					
32	GIWW E (E)									
33	Fla. Gulf					x	x	x		
34	Houston Canal			x	x					
35	Black-Warrior					x	x			
36	Alabama-Coosa					x	x			
37	Tenn-Tom		x							
38	ACF					x	x			
39	Fla/Ga. Coast		x	x						
40	Carolinas		x	x						
41	Ches & Del.	x		x	x			x	x	
42	NJ/NY Coast			x	x	x			x	x
43	*NY State Waterways*							x		x
44	U. Atlantic			x	x	x	x		x	x
45	L. Ontario	x			x					
46	L. Erie	x			x	x				
47	L. Huron	x			x	x	x		x	
48	L. Michigan	x			x	x			x	x
49	L. Superior	x			x	x	x			
50	Puget Sound		x	x	x	x	x	x		x
51	U. Columbia	x	x			x	x			
52	L. Columbia	x	x	x	x					
53	Ore./Wash Coast			x		x				
54	N. California									
55	San Francisco Bay	x		x	x			x		x
56	C/S California	x		x	x					
57	SE Alaska									
58	SC Alaska									
59	W & N Alaska									
60	Pacific									
61	Caribbean									

Table VI-2

Level of Current Use and Conflicts

GROUP 1

High Navigation Use/High Recreation Use/Conflict Segments

1 - Upper Mississippi
2 - Lower Upper Mississippi
9 - Illinois Waterway
11 - Upper Ohio
12 - Middle Ohio
13 - Lower Ohio (Three)
16 - Monongahela
24 - Arkansas and Verdigris
41 - Chesapeake and Delaware Bays
42 - New Jersey/New York Coast
46 - Lake Erie
47 - Lake Huron
48 - Lake Michigan
49 - Lake Superior
50 - Puget Sound
51 - Upper Columbia
52 - Lower Columbia
55 - San Francisco Bay
56 - Central/South California

GROUP 2

High Recreation Use/Medium No Low Navigation Use/ No Conflicts

10 - Missouri
21 - Cumberland
22 - Upper Tennessee
23 - Lower Tennessee
25 - Ouachita, Black and Red
33 - Florida Gulf Coast
35 - Black Warrior
36 - Alabama Coosa
38 - ACF
44 - Upper Atlantic
53 - Oregon/Washington Coast

GROUP 3

High Navigation Use/Medium to Low Recreation Use/ No Conflicts

3-8 - Lower Mississippi (St. Louis to New Orleans)
14-15 - Lower Ohio (II and III)
26 - Old and Atchafalays
27 - Baton Rouge Bypass
28-32 - Gulf Intracoastal Waterway
34 - Houston Ship Canal
45 - Lake Ontario and St. Lawrence Seaway

GROUP 4

Medium to Low Recreation Use/Medium to Low Navigation Use/No Conflicts

17 - Allegheny
18 - Kanawha
19 - Kentucky
20 - Green River
37 - Tennessee-Tombigbee
39 - Florida/Georgia Coast
40 - Carolinas Coast
43 - New York State Waterways
54 - Northern California
57 - Southeast Alaska
58 - South Central Alaska
59 - West and North Alaska
60 - Western Pacific
61 - Caribbean

The first and second groups were selected as the set of segments which might experience significant recreation-navigation interactions in the period covered by this study; these are the group for which detailed recreation forecasting would be undertaken.

(d) Forecasts of Future Recreation Demand

Recreation demand was forecasted for four types of facilities (locks and dams, pools and channels, ports and harbors, and reservoirs). Separate forecasts were made for four different activity types in each setting: boating (including waterskiiing), fishing, swimming, and shore-based activities (hiking, campinag, picnicking, sightseeing, and other). In each case, future recreation demand was related to four classes of variables: present levels of recreational participation, socioeconomic characteristics of the potential user population, attributes of the specific recreational sites, and distance of the potential user population from the sites.

A multiple regression method as used to forecast future recreational activity in pools and channels and to forecast future volumes of recreational craft passing through locks on the commercial waterway system. A simple multivariate model was used to forecast future recreational demand at reservoirs related to the commercial waterway system. An attempt was made to forecast future levels of recreational craft in selected ports and harbors, based upon general growth rates in boating activity.

Details of the recreational demand forecasting methodology are provided in Appendix B.

PRESENT RECREATION USE

Information on recreational use of commercial navigation facilities was sought from both Corps and non-Corps sources. Corps data includes data prepared for the NWS

Inventory and for the ongoing Recreation Resource Management System, as well as data provided by studies, documents, and interviews with Corps personnel. Non-Corps data sources included state planning agencies, other interested public and private groups, and the general literature on water-based recreation.

(a) Corps Data on Recreation Use

Data from four sources were collated by analytic segment and analysed fro the waterways system. The four sources include: recreational user-days by facility as recorded in the Corps "Recreation Resource Management System" (RRMS); recreational user-days by segment and subsegment as recorded in the NWS Inventory; data on recreational craft passing through locks, from the NWS Inventory; and data on recreational facilities at Corps-controlled ports and harbors, also from the NWS Inventory.

There appears to be very wide variation in the number of user-days reported for each segment in the RRMS and in the NWS Inventory. In part this may be an artifact of different definitions; the RRMS data are given for 1977 and the NWS data are an average for the three years 1976-1978. Furthermore, the RRMS data include only data on facilities having over 5,000 user-days per year; thus, additional facilities with lower levels of use might account for the discrepancies.

However, an inspection of the detailed data by segment reveals major inconsistencies on some segments. It is apparent that these inconsistencies are due to the fact that user-days at some facilities are counted in one system and not another. Neither the RRMS nor the NWS Inventory provides a consistently valid estimate of recreational use on each segment (See Appendix B).

By all accounts, those segments having the highest current levels of recreation use include the Upper Mississippi, the Missouri, the Cumberland, the Arkansas, the Black-Warrior and the Alabama-Coosa, the ACF group, and the Upper Columbia/Snake Waterway. In addition, high use levels are reported in the NWS inventory for the Tennessee

River, the New Jersey/New York Coast, Lake Erie, and the Oregon/Washington Coast, although these segments are not represented at all in the RRMS. Significant discrepancies exist between the NWS Inventory and the RRMS regarding recreational use of the Great Lakes, including Lake Huron, Lake Michigan, and to a lesser extent Lake Superior.

Other segments show high recreation use according to the RRMS but none in the NWS Inventory. These include the Lower Upper Mississippi (Polls 24-26) and the Florida Gulf Coast. Moderately high recreation levels are shown by both sources for the Ouachita, the Black and Red group, and Puget Sound. The Upper Ohio, the Monongahela, and the Upper Atlantic Coast all show significant volumes of recreation use according to the RRMS, although this fact is not reflected in the data given in the NWS inventory.

It would appear that moderate levels of recreation use characterize the Middle and Lower Ohio, the Allegheny, Kanawaha, Kentucky, Green, and Pearl Rivers; the Florida/Georgia and Carolina Coasts, Chesapeake and Delaware Bays; Northern California; and San Francisco Bay. A few segments have no data on recreational user-days but do have data on recreational craft, indicating at least boating use; these include the western sections of the Gulf Inland Waterway, the New York State Waterways, and the Lower Columbia.

There are seven segments for which no recreation data at all can be obtained from Corps data sources. These are Segments 4-8, covering the Mississippi River from the mouth of the Ohio to New Orleans; Segment 37, the Tennessee-Tombigbee Waterway; and Segment 61, the Caribbean.[11] Seven segments have only data on ports and harbors containing recreational facilities. These include the Houston Ship Canal, the easternmost section of the Gulf Intracoastal Waterway, Central/South California, the three Alaska segments, and the Western Pacific. Three other segments have only information on recreational craft passing through locks and dams. These are Segment 3, the Middle Mississippi, and Segments 26 and [illegible] the Old and Atchafalaya and the Baton Rouge Bypass. All the remaining segments have recreational use data from at least two sources.

Generally, it seems possible to disaggregate the inland waterways segments into locks, channels, and ports and to obtain a fairly accurate estimate of the level of recreational and commercial activity in each of these settings. It is more difficult to estimate recreational use of the Great Lakes, and almost impossible to make a complete inventory of the coastal segments due to the extensive opportunities for alternate access to the waterways system. Nevertheless, by focusing on ports, locks and channels as sites of potential conflict, it should be possible to forecast the future level of interaction between recreational and commercial activities in these settings as well.

The following paragraphs summarize Corps recreational use data by NWS reporting region.

1. Upper Mississippi. The Upper Mississippi is a heavily canalized segment containing locks and dams and associated pools. Recreation use of pools varies from under 100,000 user-days annually at St. Anthony Falls and Pool 1, near Minneapolis, to over two million user-days annually on Pools 14-16, 19 and 21. Boating use accounts for over half of all pool recreation in the upper pools and drops to around 30% in the lower pools near heavily urbanized areas where land-based sightseeing becomes more important. A total of 30 million user-days is estimated for this region in the RRMS data system and over 45 million in the NWS Inventory. The RRMS system provides complete coverage of this region.

Recreational craft use of locks is also highly significant in this area. Reported annual numbers of recreational craft passing through locks range from about 900 at L/D No. 1 to a high of nearly 10,000 at L/D No. 14. No recreational craft data are reported for Upper and Lower St. Anthony Falls or for L/D No. 4. Locks and Dams 11 through 15 meet the criterion for high-use facilities, with L/D Nos. 5A, 7, and 10 very close to this level. Congestion at locks and dams in this region may be even more severe than indicated by the general criterion, since recreational use is concentrated in a relatively short season of the year.

Recreational facilities at commercial ports are reported for five areas. Reported facilities are concentrated at St. Croix, with six marinas, over 900 slips for

commercial craft, and 11 launching ramps reported for the St. Croix River Tributaries.

2. Lower Upper Mississippi. This region reports very little recreational use. No recreational user-days are reported on these segments in either the RRMS or the NWS Inventory. Negligible number of rerecreational craft are passed through L/D No. 26. No commercial ports containing recreational facilities are reported in this area.

3. Lower Mississippi. No recreation use data of any kind have been reported by the Corps for this region in either RRMS or the NWS Inventory.

4. Baton Rouge to Gulf. No recreation use data of any kind have been reported for the two Mississippi River segments in this region. Significant use occurs only on Analytic Segment 25 (Ouachita, Black and Red Rivers) where recreational use is reported at well over a million user days in the NWS Inventory (over two million in the RRMS). The two principal locales are Columbia Pool (over a million user-days) and Jonesville Pool (over 500,000 user-ddays), both on th Ouachita and Black Rivers.

Recreational boating and waterskiing are relatively unimportant in the recreational use of these pools, accounting for 5-10% of all use. Fishing is more important (25-40%), but swimming is not (less than 10%). Land-based activities account for well over half of all recreation at these facilities.

Relatively small numbers of recreational craft are reported for locks and dams in this region with the exception of L/D No. 6, which reported over 1,000 craft annually. However, this level is far from meeting the high-use criterion set up for this study.

Only one commercial port with recreational facilities is reported for this region: Alexandria, Louisiana, with one marina (10 slips) and two launching facilities. Overall recreational use and potential conflict with commercial navigation in this region is low.

5. Illinois River. There is a large discrepancy between the RRMS, which reports under 12,000 user days at La Grange Pool on this segment, and the NWS Inventory, which reports two million user days. The latter figure is

more likely to be correct if the relationship between recreational craft locked through at La Grange and the number of pool recreation user-days (approximately 1:10) holds good for the remaining pools on the waterway. Numbers of recreational craft passing through locks range from 800 to 2500 at each of eight locks on the system, with a peak of nearly 16,000 at the T.J. O'Brien lock just above Chicago. This lock meets the criterion of a high-use facility for purposes of the recreation analysis. No commercial ports with recreational facilities are reported in this region.

6. Missouri River. Recreation use is not compiled on the free-flowing portion of the river, which is part of the commercial waterways system. On the other hand, recreation use of the reservoir system on the Upper Missouri is very heavy, reaching over 10 million user-days in recent years. Only recreation at Lewis and Clark Lake, above Gavins Point Dam, is likely to be affected by variations in lake levels caused by navigation releases for flow augmentation in the commercial portion of the river.

Recreation use of Lewis and Clark Lake amounts to over four million user-days annually. Sightseeing and other land-based activities are the most important category of use, with about 20% of visitors participating in fishing, 10% in boating and water skiiing, and 10% in swimming. There is no lock providing access for recreational boats from Lewis and Clark Lake to the lower Missouri.

7. Ohio River. There are 11 river segments in this region, including five on the Ohio River itself and six principal tributaries. Of these, the Upper and Middle Ohio and the Cumberland River can be classified as high-use segments. Tygart Lake, providing navigation releases to the Monongahela River, can also be classified as a high-use facility.

The commercial waterways in this region are extensively canalized and each pool receives a substantial amount of recreational use. Such use is spread fairly evenly over the system with a greater concentration in the more highly urbanized areas. Although Greenup and Meldahl L/Ds report no recreational craft passing through locks, and the use of these two pools on the Middle Ohio (Segment 12) qualifies them as high-use facilities. Markland L/D reports only half as many user-days but has nearly 4,000 recreational craft passing through its lock, so that it,

too, qualifies as a high-use facility. Recreational boating facilities are reported at two commercial ports: Huntington, West Virginia (three marinas with 200 total slips and two launching ramps), and Cincinnati, Ohio (16 marinas with over 600 slips and 21 launching ramps).

Recreational use of the Ohio River definitely appears to decline as one moves downstream. This may be due to an increasing concentration of commercial navigational, fewer nearby population centers, or competing shoreline uses in this area. The three Lower Ohio segments report relatively low levels of rock use by recreational facilities, Mount Vernon, Indiana (one marina with 10 slips and two launching ramps).

Recreational use of the Monongahela River exceeds one million user-days, but most of this can be attributed to Tygart Lake. The nine L/Ds and associated pools on the navigable portion of the river each receive moderate amounts of recreational use. A similar pattern prevails on the Allegheny River accept that L/D Nos. 2, 3, 4, and possibly 5 could be classified as high-use facilities based on the number of recreational craft passing through them.

Recreational use of the four pools on the Cumberland River, in contrast, is quite heavy. Each pool registers over one million user-days annually and Old Hickory and Barkley Lake are close to five million user-days each. Nevertheless there are only moderate numbers of recreational craft passing through the associated locks.

Nashville, Tennessee is the only commercial port on the Cumberland River reporting recreational facilities, and it only has one launching ramp.

Fishing is a very significant activity in each of the four pools on the Cumberland, involving 35% to 55% of all visitors. Boating participation ranges from 10% to 25% and swimming from 1% and 17%. Land-based activities account for over half of all recreation participation at Lake Barkley, but less than half at the other three pools.

8. Tennessee River. A total of 50 million user days is reported in the NWS Inventory for this region, making both the upper and lower Tennessee high-use segments. The river is canalized, but no recreation data are reported in the RRMS for the pools, presumably because

these facilities are administered by the Tennessee Valley Authority (TVA) for purposes other than navigation. Recreational craft passing through the ten locks on the river range from 500 at Melton Hill (the upper end) to 4,000 at Guntersville and Chickamanya, qualifying the two last-named as high-use facilities. Chattanooga and Knoxville, Tennessee, each have one marina and one launching facility for recreational craft.

9. Arkansas River. This canalized river also experiences heavy recreation use. There are 17 locks on the segment and substantial recreational use on each of the associated pools. A total of 15 to 20 million user-days are reported for the segment, including near two million user-days at Oolagah Lake, a reservoir with authorized navigation releases.

Particularly high recreation use is reported for Dardanelle Pool (over three million user-days), David Terry Robert Kerr, and Webbers Falls Pools (between one and two million user-days each), and Murray, Toad Suck Ferry, Ozark Lake, L/D No. 13, and Newt Graham pools (over 500,000 user-days each). However, the number of recreational craft passing through the associated locks is not particularly high except in the case of Murry L/D (about 4,000 craft). There are no commercial ports with recreation facilities reported on this segment.

Fishing is a major recreational activity throughout the region, involving anywhere from 20% to 70% of all visitors to Corps projects. Over half of all visitors to Oolagah Reservoir engage in fishing. Swimming is generally unimportant on the pools, but is a major activity on those pools with the heaviest recreation use (15% to 20% visitors to Dardanelle, David Terry, Robert Kerr and Webbers Falls). Swimming is not very important on the reservoir.

10. Gulf Coast West. No recreational user-days are reported for any of these segments either in the RRMS or the NWS Inventory. On the other hand, numerous locks exist on the commercial system which also handle recreational craft. Generally, the numbers are small, with one major and two minor exceptions. There is also a relatively large number of commercial ports with recreational facilities in this region.

Calcasieu Salt Water Barrier is a high recreational use facility with nearly 30,000 recreational craft locked through each year. Although it is physically located on the commercial waterways system, commercial craft do not use this lock. Therefore, it is not a potential site of conflict with commercial navigation.

Freshwater Bayou Lock passes over 6,000 craft annually, and Catfish Point (mernenta) Salt Water Barrier passes about 1,500. Recreational traffic at the seven other locks in this region is insignificant.

Eighteen commercial ports in this region are reported as having facilities for recreational craft. Eight of these have only launching ramps. The remaining ten have one to five marinas each. The most important locations are Corpus Christi Ship Channel (five marinas with 685 slips), Chocolate Bayou (four marinas with 140 slips), and Galveston Port Channel (two marinas with 700 total slips).

11. Gulf Coast East. Recreational user-days in this region are reported only for the inland waterway portions of the commercial waterway system, not for the coastal portions. Moderate recreational use (under 500,000 user-days) is reported for the Pearl River and the Cross Florida Barge Canal. Heavy recreational use (two to four million user-days) is reported for the Lake Okeechobee Waterway, for Lake Seminole (Jim Woodruff L/D), and for the pool above Walter F. George L/D on the Chattahoochee River. Lake Sidney Lanier above Buford Dam which is a reservoir authorized for navigation releases, receives over 13 million visitor-days per year.

Recreational fishing is an extremely important activity in this region, accounting for 30% to 50% of all visitors to the Okeechobee Waterway and the pools on the Chattahoochee. Recreational boating is much less important (less than 10%) and swimming is only slightly more important than boating (less than 12%). Over half of all visitors to these facilities engage in land-based activities. The pattern at Buford Reservoir is quite different, with nearly 30% of all visitors engaged in boating, nearly 20% in swimming, and only 18% in fishing. However, sightseeing and other land-based activities still involve well over half of all visitors to the reservoir.

Relatively small numbers of recreational craft move through locks in this region, except for the locks on the Okeechobee Waterway, which carry between 3,000 and 6,000 craft annually. Two of these locks (Moore Haven and W.P. Franklin) meet the criterion to be called high-use facilities in the region. Four have launching ramps only, while six have from one to four marinas and less than 100 slips each. Tampa, Florida, has 12 marinas and 600 slips, and St. Petersburg, Florida, has two marinas, but over 600 slips.

12. Tombigbee-Alabama-Coosa-Black Warrior. This region includes three waterway segments, one of which (Tennessee-Tombigbee) is still under construction. The two operational segments experience high levels of recreational demand, over four million user-days each. It is expected that high recreational demand will also develop on the Tennessee-Tombigbee Waterway as soon as it is completed.

All of the pools can be classified as high-use facilities. However, recreational use of locks appears to be quite moderate in comparison (less than 1,000 craft per lock per year). An examination of the pool data shows that boating and fishing are extremely important on the Alabama-Coosa, accounting for 70% to 80% and 75% to 85% of all visitors, respectively. Swimming is relatively less important (10% or less), while land-based activities also involve more than half of all visitors. On the Black Warrior lakes and pools, boating accounts for 15% to 30% or all visits and fishing for 20% to 50%. Swimming is quite significant on the Black Warrior Lakes (20%) and shore-based activities are less important than elsewhere, though they still involve over half of all visitors.

There is only one port containing two commercial marinas and a total of 35 slips in this region (Mobile, Alabama). On the other hand, 90 separate launching facilities are reported. It would seem that recreational boating in this region consists largely of craft small enough to be trailered to pools and used primarily for local recreation. There is a strong emphasis on fishing as part of the river recreation experience.

13. South Atlantic Coasts. As with all coastal regions, Corps recreational use data refer only to Corps projects. Thus, moderate use levels (about 200,000 user-days) are reported for the New Savannah Bluff pool on the

Savannah River and for three pools on the Cape Fear River. Only small numbers of recreational craft (100 to 200 per year) pass through the associate locks. No data are available on recreational use of the coastal portions of the waterway system in this region.

Six commercial points with recreational facilities are reported in this region. Of these, Miami, Florida, is by far the most important, with 70 marinas, 5,500 slips for recreational craft, and 20 boat launching facilities. All the others have one or two marinas, 100 slips or less, and one or two launching ramps.

14. Middle Atlantic Coast. This region experiences very high recreation use. On the Chesapeake and Delaware Bays recreational boating is extremely high but it is not reflected in the NWS inventory since most of the use is out of private marinas. Corps data are reported only for the two ship channels, the Albemarle and Chesapeake Canal and the Chesapeake and Delaware Canal, whose combined recreational use is about 350,000 user-days per year. The areas with the greatest recreational use reported in the NWS Inventory are New York Harbor (over eight million user-days); the South Shore of Long Island (over six million user-days); and the North Shore and Inner Forks of Long Island and Sandy Hook and Raritan Bays (over a million user-days each). The NWS Inventory does not provide a breakdown of user-days by activity type.

There are only three commercial locks in this region: Deep Creek and South Mills on the Dismall Swamp Canal and Great Bridge on the A & C Canal. The former two carry only moderate levels of recreational traffic (1,400 craft per year). The Great Bridge lock, in contrast, carries 8,900 craft per year and can be classified as a high-use facility.

There are 36 commercial ports in this region listed as having recreational facilities. The Port of New York is the largest, with 175 marinas, 22,000 slips for recreational craft, and 17 launching facilities. There are over 100 more marinas with over 5,000 total slips in the Hudson River up to Spuyten Duyvil, and 70 marinas with over 5,000 total slips in Jamaica Bay. Next in size are East Rockaway Inlet, Long Island (36 marinas, 1,680 slips), and Manhasset Bay (32 marinas, 2,310 slips).

There are 25 marinas with 1,500 slips at East Chester Creek, and 22 marinas in the New York and New Jersey Channels with a total of 1,100 slips. Then additional ports have 10 to 15 marinas and 90 to 1,300 slips each. In all a total of 646 marinas and almost 50,000 slips for recreational craft are available in commercial ports on this region.

15. North Atlantic Coasts. Recreational user-days on the Upper Atlantic are reported in great detail in th NWS Inventory. However, the total for the segment represents only a moderate level of use (about 300,000 user-days). In contrast, the RRMS records nearly two million user-days at th Cap Code Canal. However, this use is predominantly sightseeing and other land-based activities.

There are no locks and dams on this segment. In contrast, there is a large number of commercial ports with recreational facilities. The most important is boston Harbor with 72 marinas and slips for over 5,000 recreational craft, as well as 12 launching sites. The Connecticut River contains 51 marinas with approximately 3,450 slips and 13 launching ramps. Norwalk Harbor, with 18 marinas, has 2,425 slips, while New Lond Harbor, with 12 marinas, has 5,750 slips. Five other ports have from 11 to 16 marinas and from 300 to 1,000 slips. The entire region contains 277 marinas in commercial ports with a total of over 22,000 slips for recreational craft.

16. Great Lakes/St. Lawrence Seaway/New York State Waterways. The RPMS records recreational user-days for only a few selected facilities on these segments. They include St. Marys river, Sturgeon Bay and the Lake Michigan Ship Canal, the Lower Keweenaw Entry Waterway, and Duluth Ship Canal and Harbor Park. Substantial amounts of recreational use (between 900,000 and 1,000,000 user-days) are recorded for St. Marys River and for the Duluth Ship Canal and Harbor Park. However, in both cases this use consists 99% of land-based activities. Fishing is important, accounting for 40% of visitors, at both Sturgeon Bay and the Lower Keweenaw Entry Waterway. In addition, 60% of visitors engage in swimming and 10% in boating in the Lower Keweenaw Entry Waterway.

The NWS Inventory does not contain data on recreational user-days for the New York State Waterways System or for Lake Ontario and the St. Lawrence Seaway. Recreational use of all water resources has been entered

in to the NWS Inventory for applicable portions of Lake Erie, Lake Huron, Lake Huron, Lake Michigan, and Lake Superior. These data are non-comparable as they are not restricted to the commercial waterways, but they give some indication of the magnitude of water-related recreation in the area which amounts to 12 million user-days around Lake Erie, 21 million user-days around Lake Huron, 25 million user-days around Lake Michigan, and just over one million user-days around Lake Superior.

The New York State Waterways System is heavily canalized and contains more than 60 locks. All of these locks report use by recreational craft ranging from one to three thousand craft per year, with two exceptions. Utica Harbor Lock (between Locks 15 and 16 on the Erie Canal) has practically no recreational use, while L/D No. 233, at the junction of the Erie Canal and the New York State Barge Canal, has nearly 6,000 recreational craft annually, qualifying it as a high-use facility.

The 15 locks on Lake Ontario and the St. Lawrence Seaway all report relatively small volumes of recreational traffic (1,000 to 2,000 recreational craft per year). Black Rock Lock on the Niagara River passes just under 5,000 recreational craft annually. Four locks on St. Marys River between Lake Huron and Lake Superior also have low levels of recreational use, generally less than 1,000 craft per year.

There are over 60 commercial ports with recreational facilities in this region (as well as many small craft harbors constructed by the Corps). The highest concentration of slips for recreational craft is found in the Lake Clair Channels (3,785), followed by the New York State Barge Canal (2,980), Cleveland Harbor (2,915), Detroit Harbor (1,697), Erie Harbor (1,345), Saginaw River (1,287), and Lorain Harbor (1,190). Thirty-five other ports have slips for between 100 and 1,000 craft. A total of over 22,000 slips for recreational craft are available in commercial ports or on the commercial waterways in this region.

17. Washington/Oregon Coast. Recreational use of over one million user-days is recorded on each of the two analytic segments in this region. On Puget Sound, over 800,000 user-days are allotted to the Lake Washington Ship Canal and 96% of this is attributable to land-based

sightseeing. On the other hand recreational use of Puget Sound is probably significantly undercounted.

There is only one lock on Puget Sound and it is definitely a high-use facility. This is the Chittenden Salt Water Barrier, which has over 67,000 recreational craft passing through it each year. There are 12 ports with facilities for recreational craft in the region. By far the most important is the Port of Seattle with 52 marinas and nearly 7,000 slips for recreational craft as well as 33 launching facilities. All of the ports combined offer just over 10,000 slips and about 70 launching ramps.

18. Columbia Snake Waterway/Willamette River. Recreational use is heavy on the Upper Columbia and Snake Waterway, amounting to over eight million user-days according to the RRMS. Over four million of these are attributed to Lake Sacajawea behind Ice Harbor Lock and Dam. Another million user-days Umatilla (John Day L/D) and Lower Granite. The remaining four pools register recreational use of between 200,000 and 400,000 user-days each.

Despite this high pool use, recreational use of locks is rather low. The highest use is found at Ice Harbor, Lower Granite and Little Goose (over 1,000 recreational craft per year), but this is not in the range for a high-use facility as defined for this study. One lock on the Lower Columbia, at Williamette Falls, also has relatively low levels of recreational traffic.

There are three ports with recreational facilities on the Upper Columbia/Snake and eight on the Lower Columbia. The most important is Portland, Oregon, with 25 marinas and 2,324 slips for recreational craft. Scappoose, Oregon, (Multnomah Channel) has 11 marinas with 446 slips, and Warrenton, Oregon, has five marinas with 603 slips. Altogether in the region there are 55 marinas in commercial ports with a total of over 4,600 slips.

19. California Coast. The North Coast of California reports very little recreational use and the Central and South Coast report none, indicating that recreational activity is generally well separated from the commercial waterways. However, moderately heavy use is reported for San Francisco Bay (about 400,000 user-days). There is one

lock, the W.G. Stone Salt Water Barrier protecting Sacramento Bay, which carries over 7,000 recreational craft per year.

Fourteen ports on the California Coast report recreational facilities. San Diego has over 5,000 slips for recreational craft and four launching ramps. Los Angeles has over 3,000 slips but only one launching ramp. Long Beach has just under 3,000 slips and also only one launching facility. Oakland Harbor reports 2,500 slips and nine launching ramps; Sacramento, 1,300 slips; San Francisco Harbor, 1,050 slips and three launching facilities; and Richmond Harbor, 1,000 slips and five launching facilities. Stockton, California, reports over 150 marinas without giving the number of slips; this number is probably well over a thousand. Altogether, the region contains at least 18,000 slips for recreational craft and 33 launching ramps at or near commercial ports.

20. Alaska. There is no recreational use reported on the commercial waterways in Alaska in either the RRMS or the NWS Inventory. There are no locks in this area. Ten ports report facilities for recreational craft ranging from one to three marinas and from one to five launching facilities. The largest recreational use of ports occurs at Ketchikan (820 slips), followed by Sitka (690 slips), Seward (465 slips), and Wrangell (300 slips). The total number of slips available in commercial ports in this region is less than 3,000.

21. Hawaii and Pacific Territories. Few data are available on recreational use of the commercial waterways in this region. Recreational facilities are reported at the ports of Hilo and Kawaihae but these are relatively small (60 and 30 slips respectively and one launching ramp at each harbor.)

22. Caribbean. No recreational use data at all are available for this NWS reporting region. It is inferred that recreational activity and commercial navigation go on independently of each other and a physical separation of uses is maintained in this region.

(b) <u>Non-Corps Data on Recreation Use</u>

Other sources were consulted in an attempt to establish additional information on recreational use of the commercial waterways system. These sources were generally found to be of uneven quality, consistency and comparability. In most cases, the available data could not be disaggregated into data pertinent to the commercial waterways system and data pertinent to other water resources. It was decided, therefore, to use Corps data which were available on a systemwide, segment-specific basis rather than to attempt the massive data collection and processing efforts which would be required in order to incorporate data from other sources into the analysis.

<u>1. State Comprehensive Outdoor Recreation Plans (SCORPs).</u> Under Public Law 88-578, all states are required to prepare state-wide comprehensive outdoor recreation plans in order to qualify for funds available through the Federal land and Water Conservation Program. A SCORP from each state is kept on file at the Heritage Conservation and Recreation Service, Department of the Interior. SCORPs (California and Louisiana) were unavailable in the Bureau of Outdoor Recreation files.

SCORPs generally employ more or less the following format:

(a) Statement of goals and objectives for outdoor recreation planning.

(b) Discussion of agencies involved in providing recreational opportunities, their responsibilities and areas of activity.

(c) Description of the recreation planning process.

(d) Description of present state plans and programs to provide recreational opportunities.

(e) Description of state physical and socioeconomic characteristics.

(f) Estimation of future demand for outdoor recreation.

(g) Inventory of recreational sites and facilities available to meet demand.

(h) Assessment of future recreational needs (excess of demand over supply).

(i) Proposed new programs to meet needs, including those proposed for federal assistance.

The level of detail in which each of these subjects is treated varies greatly from state to state. No common set of measure for recreational demand or supply is used. The data, therefore, are of varying quality and utility.

Most states present data organized by substate planning regions, which are usually aggregates of counties. Data may be broken out to the county level either in the SCORP itself or by consulting the state planning officials who prepared the SCORPs. Data are generally organized according to a fairly standard set of recreational activities which can be divided into those which are land-based and water-based. Some states inventory available surface water and actual water use for recreational purposes, but they do not generally distinguish between those water resources which are part of the national waterways systems and others.

Methodologies used for forecasting recreational demand range from the very simple "trend growth" type of model to the highly complex, multivariate regression type of model linking demand to a rarity of socioeconomic and physical parameters. Supply is generally viewed as limited by capacity and funding constrants. Few states analyze the issues surrounding multipurpose use of facilities and the constraints on both supply and demand for recreational facilities that may arise out of these issues.

<u>2. United States Coast Guard Surveys</u>. The United States Coast Guard is responsible for insuring the safety of travel on the nation's navigable waterways. In this capacity, it keeps detailed records of boating accidents and conducts a program to promote safe boating conduct. The Office of Boating Safety is responsible for the

safety of recreational craft and the Office of Marine Safety is responsible for commercial craft.

The Coast Guard has conducted two nationwide surveys on recreational boating, one in 1973 and one in 1976. The survey data are intended to supplement boat registration and accident reports as measures of boating activity. Considerable amounts of detailed information are provided on the characteristics of boats, boat ownership and use, boat operators and boating households. Survey data on boating accidents provide a check on data developed from official accident reports.

The survey results show a rapid recent expansion in recreational boating. The estimated number of boating households grew by over 40% between 1973 and 1976, or about 12% per year, and in 1976, they comprised about 25% of all households in the continental United States. Over 75% of all boating households participate in recreational fishing using boats, and over 60% in sailing or cruising for pleasure. Less than 40% are engaged in water skiing, and under 20% in canoeing and kayaking. The survey data provide valid estimates of participation at the national level, but because of the survey design and sample size, cannot be disaggregated to lower levels.

3. Other Data Sources. A review of documentary materials provided by the Corps and a review of the recreation planning literature in general were carried out in order to identify additional references that might be useful for this study.

A number of studies related to water-based recreation were provided to the study team by the Corps. These included studies sponsored by the Corps and other documents which had come to their attention. Specific studies were made available with regard to ports and harbors (Puget Sound, Grays Harbor and Willapa Bay in Washington, Portland, Oregon, North Coast of California, Northport Harbor and Manitowoc Harbor in Wisconsin), marinas (Lake Michigan and Tenn-Tom Waterway), and locks (Upper Mississippi and Illinois Waterway). More general studies addressed urban recreation needs, marine recreational fisheries, river recreation management and recreational boating on a nationwide scale.

Bibliographic references were reviewed and library resources, including journal literature, were systematically search for materials on water-based recreation and multipurpose use of water resources. Those references which were found to be relevant are included in the Bibliography at the end of this report. It would appear from the literature review, that relatively little research attention has been paid to recreation taking place along the Commercial Waterways system, as opposed to research focused on recreation or wild or scenic rivers, lakes, reservoirs and shorelines.

In general, the literature consists of three categories: (1) general works on methodology or models for estimating supply and demand of water-based recreation; (2) specific studies of present or purposed recreational or multi-use facilities; and (3) symposia or collections of articles centering about a theme such as river recreation or marine fishing. While the literature review was useful in providing general background information, it added little to the information already collected regarding recreational use of the Commercial Waterways system, and there still exists major gaps in data concerning use of present waterways, mooring slips available and specific interactions with commercial tows or other waterway uses.

INTERACTIONS BETWEEN RECREATIONAL ACTIVITY AND COMMERCIAL NAVIGATION

Several activities were undertaken in order to identify the range of present interactions between recreation and commercial navigation on the waterways system. Data were initially collected in interviews which were held with Corps personnel at the division level. United States Coast Guard accident statistics were examined to see if they could provide a reliable indicator of conflict in certain areas. Finally, the literature review and contacts with other agencies were also directed to this issue.

Based upon the identified range of interactions, a set of segments was selected for more detailed case study. The case studies were placed in a comparative perspective and used to develop a conceptual framework for understanding and predicting interactions in the future.

(a) Interactions Identified in Corps Interviews

The Corps was requested to provide specific information regarding recreation/navigation conflicts in interviews conducted at the Division level. The following conflict areas were identified:

1. Lower Mississippi Valley. Congestion occurs in locks and pools along the Lower Middle Mississippi, particularly locks 25 and 26, sometimes causing excessive delays to recreational craft and creating a potential safety hazard. There is also one river port experiencing problems with commercial traffic at a nearby marina.

2. North Atlantic. No recreation/navigation conflicts were identified. The timing of dredge action and disposal in the Hudson sometimes presents a problem with regard to environmental concerns and fishing and hunting activities.

3. South West. Recreation (fishing) and navigation (fleeting) are competing uses on the oxbow lakes formed by channelization of the Arkansas and Verdigris Rivers. This is not a present, but a potential conflict situation. There is also a trade off between the navigation impacts (positive) and the recreation impacts (negative) of tapering reservoir releases.

4. South Pacific. Congestion and conflict between recreational and commercial craft are reported in San Francisco Bay and expected with the future expansion of Richmond Port. There may also be a present or potential conflict in the delta channels. Channel conflicts are also reported in Los Angeles Harbor.

5. North Pacific. Conflicts are reported between deep draft (commercial) vessels and smaller craft, including recreational craft, due to wave effects. These waves also have a negative impact on beaches and levees.

6. North Central. Congestion in locks on the Upper Mississippi has been identified as a conflict involving recreational craft. Potential conflicts may also occur as a result of major withdrawals from the Great Lakes or variations in lake levels in the future.

7. Ohio River. A conflict between recreational boating and commercial port and fleeting activity has been identified on the Lower Ohio (Louisville District).

8. South Atlantic. No recreation conflicts were identified by the Corps. However, navigation releases from reservoirs on the Chattahoochee River do have a negative effect on reservoir recreation potential.

In addition to conflicts between recreational and navigational water uses, the Corps identified several instances of beneficial impacts or complementary uses. These involve situations where navigation improvements have provided additional benefits to recreation. Examples include: Construction of a recreational-craft-only lock on Puget Sound to restrict salt water intrusion; Construction of levees for flood control on the Ohio and Mississippi providing public access for fishermen; Use of notched dikes along the Arkansas which create a favorable habitat for fish; Inclusion of fish ladders in the design of locks and dams on the Columbia and the general benefits of recreational use of facilities constructed primarily to serve navigation or other uses, such as ports and harbors, locks, channels and reservoirs.

(b) United States Coast Guard Accident Data

The Coast Guard is responsible for collecting and reporting accident data on the commercial waterways. Two data printouts were provided by the Coast Guard. One list shows all reported accidents in 1978 listed by County reporting. The printout shows the type(s) of craft involved and whether or not a fatality resulted from the accident. A second printout lists only those accidents involving collisions between commercial and recreational craft over a two-year period.

The first conclusion to be drawn from an examination of these two lists is that accidents involving both recreational and commercial craft represent a very small share of all accidents. Most accidents involve either collisions between a boat and a stationary or moving object in the water.

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Based on its survey findings, the Coast Guard estimates that 95% percent of all non-fatal accidents go unreported, but only one percent of fatal accidents. The fatal accidents are therefore, a much more reliable indicator of severe safety hazards, although non-fatal accidents may suggest the location of congestion and conflict on the waterways system.

The data on accidents involving both commercial and recreational craft were compiled by analytic segment. The results revealed that over a two-year period, only thirteen segments had five or more accidents reported. Only one segment had more than two fatal accidents (Segment 24 - Arkansas, Verdigris, White and Black Rivers) while two segments had two fatal accidents and nine segments had one each. The following segments were identified as having high accident levels (five or more):

1. 1 - Upper Mississippi (5).
2. 9 - Illinois Waterway (7, including 2 fatal).
3. 34 - Houston Ship Canal (5, including 1 fatal).
4. 39 - Florida/Georgia Coast (13).
5. 40 - Carolinas Coast (8, including 1 fatal).
6. 41 - Chesapeake and Delaware Bays (18).
7. 42 - New Jersey/New York Coast (18).
8. 44 - Upper Atlantic (20).
9. 50 - Puget Sound (7).
10. 53 - Oregon/Washington Coast (7, including 1 fatal).
11. 55 - San Francisco Bay (8, including 1 fatal).
12. 56 - Central/Southern California (30).

It is clear that most accidents involving recreational and commercial craft occur on the coastal waterways or in major coastal harbors. (This may, however, reflect a greater probability that coastal accidents will be reported to the Coast Guard.) Fatalities, however, seem somewhat more likely to occur on river segments. Five fatal accidents occurred on the Ohio River during this period (on four different segments), one on the Pearl River and one on the Black Warrior River, in addition to those recorded above.

(c) Contacts With Other Agencies

Six agencies, other than the Corps, were initially identified as potential sources of data regarding recreation-navigation interactions. These included the following:

1. River Basin Commissions.

2. the United States Coast Guard.

3. the Bureau of Outdoor Recreation, Department of the Interior (recently renamed the Heritage, Conservation and Recreation Service).

4. the Fish and Wildlife Service, Department of the Interior.

5. the American Boat Owners Association.

6. the Boating Industry Association.

7. the Sierra Club.

8. Office of Coastal Zone Management (OCZM).

The Coast Guard provided the boating statistics and accident data summarized above as indicators of potential conflict.

The River Studies Office of the Heritage, Conservation and Recreation Service indicated that it could provide no

information on recreation except for that found in the SCORPs.

Representatives of the Fish and Wildlife Service indicated that there is some concern about the flow requirements for successful maintenance of habitat for different types of fish. Where this has become a local issue, flow requirements have been established for certain streams and regulation of flows for "fish and wildlife" purposes has become an authorized use of Corps facilities.

The principal function of the Boat Owners Association is to provide information to boat owners regarding the location and scope of boating facilities. It also provides political representation to boat owners as an economic interest group. The organization has not resolved any conflicts between recreational boating and commercial navigation.

It was not possible to arrange for an interview with a representative of the Boating Industry Association. Initial contacts indicated that this source was not likely to provide significant information regarding recreation-commercial navigation conflicts.

A representative of the Sierra Club expressed concern over lock and dam construction as it may relate to changing environmental characteristics. The Sierra Club has become involved in this issue with reference to proposed changes at Lock and Dam 26 on the Lower Upper Mississippi River. It can be expected that future changes in commercial navigation facilities will be closely monitored by this and other environmental organizations to insure the identification and mitigation of adverse impacts on recreation resources.

A number of regional and planning groups' river basin commissions whose territory includes portions of the commercial waterways system were contacted to see if they

could identify additional recreation-navigation interactions. The following groups were contacted:

- Missouri River Basin Commission.
- Pacific Northwest River Basin Commission.
- Pacific Northwest Regional Commission.
- Ohio River Basin Commission.
- Upper Mississippi River Basin Commission.
- Ozark Regional Commission.
- New England River Basin Commission.
- Great Lakes Basin Commission.

These commissions were established under the Water Resources Planning Act to provide an integrated planning capacity at the river basin level. Their work is partially reflected in the National Water Assessment published by the Water Resources Council in preliminary form in 1978. In general, this study indicates that recreation/navigation conflicts are perceived as insignificant in comparison to recreational conflicts with other water uses such as energy, agriculture, and industry. The recreational value of water resources is closely linked to the preservation of environmental values, including maintenance of stream flows, wetlands areas and coastal protection.

On the other hand, recreational boating is recognized as a constraint on navigation at points of congestion such as locks and fleeting areas. Recreational facilities also compete with commercial uses for valuable shorefront property. Thus, the perspective of this national assessment is that recreational demand is becoming a constraint on commercial navigation rather than the reverse.

The river basin commissions have also completed several area-specific studies in which recreation information is included. Specific studies are available for sections of the Missouri River, the Columbia and Willamette River,

the Monongahela River, the Upper Mississippi Basin, Southeast New England and Port of Hartford, and the Great Lakes.

The Office of Coastal Zone Management (OCZM) has identified an increasing number of recreation groups and activities that are competing for a relatively fixed amount of shore area. Coastal use tends to be concentrated around public access points, many of which are part of the national waterways system. With limited public access, it is difficult to disperse uses in order to avoid conflicts resulting from high intensity of use. One of the major purposes of the OCZM is to provide assistance to the states in addressing such problems and in developing plans for coastal management.

The OCZM has found that shoreline land uses are directly related to surface water uses and particularly to the presence of multiple uses involving conflicts. Studies are underway in a number of individual states concerned with this issue. The OCZM provided a list of project managers in the coastal states who could provide further information on these studies.

(d) Results of the Literature Review

In spite of the vast array of literature devoted to recreational use of water resources and the somewhat smaller volume of studies on commercial navigation, very little work has focused specifically on the interaction between recreational and commercial activities on the nation's waterways. While providing a useful technical background and baseline data for analysis, the literature is not much help in establishing a range of recreation/navigation interactions. One exception is a document prepared by the Boating Industry Association for the Office of Coastal Zone Management.[12] This report stresses the need to identify carrying capacities for waterways in relation to the recreational value of boating and to re-orient federal priorities with regard to recreational and commercial use of the waterways system.

In another sense, however, the studies of specific present and proposed facilities arise out of a perception of a problem that often reflects conflict between recreational and commercial use of existing facilities. Such is the case with the numerous studies of locks and dams along the Upper Mississippi, for example, as well as the plans for port and harbor expansion on the Pacific Coast and the prospective study of marinas on the Tennessee-Tombigbee Waterway. By implication, therefore, these studies also help to show the range of recreation-navigation interactions and the possibility of responding to conflicts by developing new facilities, by adopting new technologies, or by implementing new techniques of resource management.

Clearly, interactions range from conflicting to complementary uses. Severe conflicts seem to arise when water surface space is inadequate to meet demand, as in the case of locks and harbors used by both recreational and commercial craft. Complementary uses are found when facilities increase the amount of water surface space available for multipurpose use, as in the case of reservoirs, or when facilities enhance, directly or indirectly, the recreational value of a water resource, as with levees.

One approach to determining a range of recreation/navigation interactions would be to look at specific recreational activities. Recreational boating seems to come most often into conflict with commercial navitation. The facilities and space required by the two uses (given a similar size and type of craft) are identical. Therefore, the two uses are in direct competition for a fixed amount of resources (channel area or lock space, for example.

Recreational fishing may be negatively affected by commercial navigation, but this potential interaction is little discussed in the literature. Channelization of streambeds, regulation of flow, and the noise and pollution associated with commercial vessels most probably have an impact on the quantities and types of fish available. On the other hand, many waterways facilities provide benefits to recreational fishing by providing public access to the shoreline, by creating new ecological niches, and by facilitating fish migrations to their spawning grounds.

Other major water-based recreational activities include swimming, rafting, tubing, water skiiing and surfing. Swimming, tubing and surfing imply prolonged immersion and suggest that a minimum standard of water quality will be required. All of these uses will create hazardous conditions if there is not a clear delineation of space to be used for recreation and navigation activities.

The presence of a water resource also enhances many land-based activities such as hiking, bicycling, camping, picnicking and beaching. Again, the quality of the experience will depend on the perceptions and preferences of the user. Commercial navigation does not compete directly with land-based recreational activities except to the extent that it preempted shoreline space for commercial storage and port facilities. Indirectly, navigation and facility construction and maintenance impacts on shores and stream banks may affect the future character of land-based recreational activities.

One way of characterizing recreation/navigation interactions is by the setting in which they take place: locks, pools, reservoirs, channels and harbors, for example. This classification system has some operational utility in terms of how conflicts are perceived by waterway users, although it seems of little heuristic value to explain the generation of conflicting vs. complementary uses. It is noteworthy, however, that salient conflicts seem to be generated in areas where water space is at a premium, e.g., locks and harbors, and are relatively less significant where space is not a major constraint. This suggests a model in which a certain amount of water surface and/or shoreline space is required for the successful operation of such activity and conflicts arise out of space demands in excess of capacity. This model seems particularly applicable to the case of recreational boating, but could possibly be extended (using other resource parameters, perhaps, such as water quality or flow characteristics) to conflicts with other recreational uses.

Another way of conceptualizing the recreation/navigation interaction is in terms of direct and indirect impacts. Thus, recreational boating and commercial navigation are in direct competition for the same resource: surface water space. To some extent this includes other

boat-based activities, such as fishing, rafting and water skiing. Swimming, surfing and tubing also present a situation of direct competition with commercial craft for surface water space. Other recreational uses are impacted indirectly by commercial navigation through its effects on water quality, streambed morphology and flow characteristics, fish and wildlife, and cultural and aesthetic qualities associated with a water resource.

A theme that runs through the recreation literature is the need for more urban-based recreational opportunities and for facilities more readily accessible to people with lesser amounts of disposable income. This theme suggests an area in which the waterway system may have a great deal to contribute, as the needs of commercial navigation bring it into the more densely populated portions of the country. In contrast, certain types of recreational demand are more appropriately satisfied by the types of facilities envisioned on "restricted" rivers, i.e., rivers closed to commercial navigation. The national waterways system will naturally be less concerned with satisfying these types of recreational demand.

DETAILED ANALYSIS OF SELECTED SEGMENTS

The identification of factors associated with present conflict situations along the waterways was carried out through a series of case studies focusing on those areas which have been identified by the Corps and other sources as conflict settings. These included the following types of settings: reservoirs and lakes, locks and pools, ports and harbors, and coastal waterways. These case studies provided an opportunity to investigate conflicts with the major types of water-based recreational activity: boating and water skiing, fishing, swimming and other water contact sports and land-based activities (hiking, camping, picnicking, sightseeing, etc.).

Nine segments were selected for case studies focusing on existing or potential recreation/navigation conflicts. The types of conflict analyzed included: congestion at locks and dams, port and harbor conflicts, fleeting area conflicts, impacts of variation in water levels on shore-based recreation, bank erosion, and dredging impacts. A

tenth case study was later carried out concerning speed restrictions on towboat operation due to the presence of marinas.

In addition, three special studies were conducted focusing on reservoir recreation and on decision-making regarding future recreation and navigation uses on a prospective waterway. Finally, accident data for one segment were examined in order to determine if they can be used as a reliable indicator of present or potential recreation-navigation conflict.

Each case study focused on one specific major conflict between commercial navigation and recreational use. In addition, secondary recreation/navigation conflicts and conflicts with other uses (hydropower, irrigation, etc.) were identified. Specific attention was given to identifying beneficial interactions or complementary uses. After the case studies were completed, a comparative analysis was conducted to determine what features of these conflict situations and complementary uses could be incorporated into a model for predicting future recreation/navigation interactions.

The following segments were selected for case studies.

1. 1 - Upper Mississippi.

2. 2 - Lower Upper Mississippi.

3. 11 - Upper Ohio.

4. 13 - Lower Ohio (Three).

5. 16 - Monongahela (Tygart Lake).

6. 24 - Arkansas and Verdigris.

7. 37 - Tennessee-Tombigbee Waterway.

8. 38 - Apalachicola, Chattahoochee, and Flint (Buford Reservoir).

9. 39 - Florida/Georgia Coast.

10. 41 - Chesapeake and Delaware Bays.

11. 49 - Lake Superior.

12. 51/52 - Upper and Lower Columbia.

13. 55 - San Francisco Bay Area.

14. 56 - Central/South California (accident data).

This sample covers 11 out of 22 NWS reporting regions. It includes all the regions where present recreation-navigation conflicts or complimentary uses have been reported. The regions which are not covered have generally low levels of recreational demand on the commercial waterway system and are areas where recreation is not a major problem for Corps planners. They include:

- Lower Mississippi.

- Baton Rouge to Gulf.

- Illinois River.

- Missouri River.

- Tennessee River.

- Gulf Coast West.

- North Atlantic Coast.

- Washington (Oregon Coast).

- Alaska.

- Hawaii and Pacific Territories.

- Caribbean.

The Illinois Waterway is an exception to the above since it does experience high recreation use. A high accident level in this region may indicate potential congestion problems. However, the situation on the Illinois Waterway should be adequately illustrated by case studies conducted on the Upper and Middle Ohio. Similarly, Puget sound on

the Oregon/Washington Coast may be a focus of potential conflict, but its situation is similar to that described for San Francisco Bay and Chesapeake Bay. The two reservoir case studies were expected to represent all four reservoirs with navigation releases, including Gavins Point on the Missouri River and Oolagah on the Arkansas.

The case studies are presented on the following pages. The first six case studies concern river segments; the next three, coastal segments; the next three, lakes and reservoirs. The last two case studies concern a canal segment not yet in operation (the Tennessee-Tombigbee Waterway and an investigation of accident data on a coastal segment (Central/South California).

(a) Upper Mississippi

1. Introduction. NWS Segment 1 consists of the main stem Mississippi River from the head of navigation at St. Anthony's Falls (St. Paul) to Lock and Dam 10 near Guttenberg, Iowa, a distance of 238.6 miles. The first three locks in the segment, Upper St. Anthony's Falls, Lower St. Anthony Falls, and L&D 1, each have a single functioning lock chamber 56' wide x 400' long. The remaining 10 locks (L&D 2-10, including 5A) have single functioning chambers 110' wide x 600' long. Most of these facilities have unfinished small auxiliary lock chambers. Pools 1-10 range in length from six to 44 miles, with 15 to 30 miles as the typical length. In general, these lock and pool characteristics are common to the entire Upper Mississippi down to L&D 26. The whole system, experiences substantial recreation-derived lock congestion.

Commercial traffic is heavy, increasing downstream with most locks experiencing over 2,500 commercial lockages per year. This traffic is relatively steady throughout the week, with a peak in August and early September. Traffic ceases from December through April when the waterway freezes up (St. Paul and Rock Island Districts close down navigation operations in winter; St. Louis District remains open). In contrast, the very heavy recreational traffic experienced in St. Paul District - the number of recreational lockages now matching or exceeding commercial lockages now matching or exceeding commercial lockages - is predominantly a peak phenomenon,

occurring mostly on weekends and holidays from Memorial Day to Labor Day. It is during these periods that recreational/commercial congestion occurs.

In general, recreational usage is heaviest in the pools which have large numbers of marinas and along which are a significant number of small towns. The Corps has extensively studied the factors related to pleasure boat lockage for the Upper Mississippi, but could find no distinct patterns or trends.[13] Such lockage appears to be the result of very mixed and localized factors, with boats moving between pools for long cruises, short trips, or to escape crowded areas.

2. Statement of the Problem. The major recreational/commercial conflict on the Upper Mississippi concerns lock congestion and recreational boating. The St. Paul District has identified Locks 1,2,3, and 10 as having the greatest congestion and expects that these problems will soon extend to Locks 4 and 7 as well.

Secondary conflicts consist of underway conflicts and accidents between the two types of craft, which are generally low. A different kind of secondary conflict regarding recreational use of wildlife refuges may soon arise between recreational boaters and environmentalists.

Any accounting of benefits to recreation from navigation improvements must include the entire navigation and flood control system, which has made safe and convenient sport boating possible. Specific benefit include the creation of popular sand beaches with dredged material; the dredging of the 11 small boat harbors built in the District by the Corps; and the introduction of keel sailboating on the river, made possible by the maintained nine foot channel depth. Dredging has also been the source of some conflict and potential conflict, especially concerning sandy beaches.

3. Description of the Major Conflict. The existing and imminent conflict recognized by the District at Locks 1-4, 7, and 10 is based on competition between recreational and commercial craft for use of a single chamber facility during summer weekends and holidays. An important generating factor is the large number of marinas and boaters in the adjoining pools. However, neither the District not the Corps' previously mentioned lockage study

has been able to determine more precisely the factors creating lockage congestion or the threshold usage beyond which a conflict may be identified. This is largely because the determination of a conflict is relative and perceptual, depending on the participants involved. In this case, they include middle class boaters, who place a high value on their limited weekend recreation time; towboat captains, who are used to delays and slow approaches at lock facilities; and corps lockmasters, who must accommodate all users safely and efficiently, yet give priority to commercial craft.

Commercial and recreational users make the Corps aware of their lockage problems in different ways. Generally, recreational boaters are not organized and do not complain directly to the District, but channel their complaints directly to the lockmasters at each facility. One exception to this occurred in LaCrosse several years ago, where the large boating community was able to organize and pressure elected officials to fund a lockage study. Commercial interests, on the other hand, sort out their problems with the Coast Guard and with the St. Paul, Rock Island, and St. Louis Districts at an annual meeting.

In such meetings, commercial interests have expressed their awareness of the potential political strength of recreational boaters and their willingness to compromise with them. Policies reflecting this attitude have already been put into effect. For example, the recreationally popular St. Croix River is used commercially only by the Northern States Power Company (NSP) to ship fuel to its generating facility on the St. Croix shore. Voluntarily, to avoid potential conflict, NSP rescheduled its barge traffic for night-time operation only. Then, as a result of a few accidents between the barges and inebriated or inexperienced boaters, NSP shifted all commercial navigation to weekdays only, effectively avoiding recreational use, which is concentrated on weekends.

Recently, the District experimented with posting weekend lockage times for recreational craft at Locks 2 and 7. The experiment set aside four 45-minute periods for recreational lockages on weekends at each facility. Although the same system is working well at L&D 25 (St. Louis), the St. Paul District discontinued it last year on the basis of data which suggested insufficient response by recreational boaters. The posted time system was carried out with cooperation of commercial interests, and it still

has support in the District in a modified form which would permit morning and evening posted times for recreational lockage priority, as opposed to exclusive lock use.

Another possible answer is the development of queuing facilities at each lock, including mooring and shore facilities, which would eliminate the stress and hazard caused by small craft milling around lock entrances. One problem with this solution is that, at present, such facilities would have to be built under a local cost-sharing system, which would be difficult to implement at locks in rural areas. Also, such facilities would involve building access areas near a lock, just where they are most dangerous.

The Corps has also investigated other potential solutions to recreational/commercial lockage congestion. These solutions were analyzed in the Recreational Craft Locks Study. They in cluded regulatory or "soft" measures, such as better public communications and boater education, in addition to posted lockage times and queueing or tie-up facilities. Other possible solutions studied include a large number of structural measures, including new locks; floating locks; mobile boat carriers; railway and inclined lifts; and completion of the present auxiliary lock chambers. The study concludes that it is difficult to justify costly structural measures given the "peak period" nature of recreational/commercial lockage congestion and the great potential for regulatory measures, as indicated by the success of the posted lockage time program at L&D 25.

4. Description of Secondary Recreational Navigation Conflicts. There are no significant secondary conflicts on this segment. Boating accidents, as in many other Districts, only rarely involve commercial craft and typically are only 5-10% of total accidents. While the creation of sandy dredge material spoil islands has generally proved to be a great benefit to boaters, swimmers, and campers, a conflict may arise over the future disposal of dredged material, especially as it affects these islands. Enthusiastic spoil island users have sometimes expressed opposition to dredging, in part, it appears, because they are unaware that the islands were created with dredged material.

A different kind of conflict may develop between boaters and environmentalists over the issue of increased recreational access to designated wildlife areas along the waterway, particularly the Upper Mississippi Fish and Wildlife Refuge between Pool 4 (Lake Pepin) and Rock Island.

5. Description of Benefits/Complementary Uses. As elsewhere in the inland waterway system, the Corps' total effort in navigational and flood control improvements must be counted as an overall benefit for recreation, for it is the control of the river that makes steady and safe recreational use possible. More specific benefits can be identified, such as the dredging of the small boat harbors built by the Corps at Redwing, St. Paul, Hastings, Lake City, Pepin, Bay City, Wabasha, Alma, Winona, Lansing, and Prarie du Chien. The construction of such harbors also provides direct recreational benefits. The dredging and maintenance of the nine-foot channel, along with these harbors, has spurred the growth of keep sailboating, which requires depths of four to five feet. Finally, the creation of sandy islands with dredged material has generated an unexpected recreational benefit for boaters and small craft-borne swimmers and campers.

(b) Lower Upper Mississippi

1. Introduction. The Lower Upper Mississippi comprises the northern end of the Corps of Engineers' St. Louis District, including the stretch of the Mississippi from Locks and Dams 24 (Nile 273.4) through 26 (Mile 202.9). The segment includes the confluence of the Illinois and Mississippi Rivers, which occurs between Locks and Dams 25 and 26. It contains numerous marinas and other river access facilities. Locks and Dams 24 and 25 are similar in design to other locks on the Upper Mississippi below the St. Anthony Falls, each having a main 600' x 100' lock chamber and an unfinished auxiliary chamber (upper lock gates and sill only). L&D 26 has both the standard main lock and a completed 100' x 360' auxiliary lock.

Both commercial and recreational traffic are heavy on the segment, and consequently so is use of the three locks. However, the pattern for the two kinds of

traffic is very different. Commercial traffic is relatively steady throughout the week and continues year round with a peak during the August/September harvest season. Commercial lockages increase from L&D 24 to 25 (following a relatively steady pattern of increasing commercial lockages from St. Paul/Minneapolis downriver) and jump three-fold at L&D 26, largely because of the traffic contributed by the Illinois Waterway. Recreational usage, by contrast, is concentrated in the pools, and recreational use of the waterway is concentrated in the months of May through September, peaking on the weekends during this time. Recreational lockage is high at L&D 24 and 25, and low at L&D 26.

1977 Lockage Figures, St. Louis District, Corps of Engineers

	L&D 24	L&D 25	L&D 26
Commercial lockages	5,248	5,671	14,048
Recreational lockages	895	1,048	329

These differing recreational and commercial patterns create somewhat anomalous conditions at the locks. Thus, it is that L&D 25 has a severe recreational/commercial lockage conflict, rather than L&D 26, which is the most critical commercial bottleneck on the Upper Mississippi. It is tempting to draw the conclusion that recreational craft are avoiding heavy commercial traffic at L&D 26, but this is not the case. The river below L&D 26 is uncontrolled and relatively hazardous for small craft; it is generally ventured upon only by cruising boats making long trips downriver. Consequently, there are very few marinas or boat access areas below L&D 26, and St. Louis area residents generally must drive to Pool 26 to use the Mississippi. When these boaters take long day or weekend trips, they tend to go upriver, through L&D 25.

The major center of population and employment in the segment is the St. Louis SMSA. The only other significant center is the town of Alton, Illinois (population 40,000) at the location of L&D 26, which contains a number of large manufacturing concerns. In general, the segment has proportionally fewer centers of population along the shore than St. Paul and Rock Island Districts. Moreover, because of the 20-mile distance from St. Louis to L&D 26 and the poor recreational quality of the river at St.

Louis, metropolitan area residents are not as oriented to river recreation as they are in St. Paul or Rock Island Districts. The St. Louis District feels that the recent gasoline shortage, along with flooding, has helped to stabilize recreational usage in the District over the past seven years.

2. Statement of the Problem. The major conflict involving lock usage on the Lower Upper Mississippi is the commercial congestion at L&D 26, where lockage delays average two hours per tow throughout the year and rise to 20 hours per tow during the August/September peak period. At this peak time, it is typical for 40 to 50 commercial tows to be waiting for lockage. Because the auxiliary lock at L&D 26 is only 100' x 360' and requires five lockages to pass a standard tow, it cannot help to alleviate commercial congestion.

The auxiliary lock handles all recreational vessels passing through L&D 26. However, there are relatively few such lockages, and these probably could be handled during the half-hour period required for a tow to approach and line up to the main lock. A recreational lockage, relatively simple if few vessels are involved, takes about 20 minutes. Ironically, this auxiliary lock could be much better used at other places in the Upper Mississippi where commercial traffic is lower but recreational traffic is much heavier.

The primary recreational/commercial conflicts on the Lower Upper Mississippi are the congestion and lock delays at L&D 25, which are now being mitigated by the Corps' experimental regulatory measures. The most significant secondary conflict in the segment concerns recreational boating safety and recreational craft accidents in all pools. The disparity in recreational use of the river above and below L&D 26 emphasizes the fact that river recreation - particularly boating - owes its existence to the Corps' overall efforts to control the river.

3. Description of the Major Recreational Conflict. The recreational/commercial conflict at L&D 25 concerns the competition for use of a single 110' x 600' lock chamber, largely during weekends from May through September, generated by heavy long range commercial traffic and the movement of recreational craft between Pools 25 and 26. This recreational movement is rooted in the large number of marinas and launching facilities in Pool

26, which is the section of controlled river closest to the St. Louis metropolitan area, and the presence of open river below L&D 26, which forces recreational boaters to take their craft upriver for longer journeys.

Commercial navigation interests express their views to the Corps (at an annual meeting of the Coast Guard), towboat companies, and St. Louis, Rock Island, and St. Paul Corps Districts, while recreational boaters generally make known their concerns through the Corps lockmasters at each facility. Here, as in the Upper Mississippi, a two hour lockage delay that is commonplace to a towboat captain is intolerable to a middle-class, taxpaying boater, who has a limited amount of weekend recreation time. This conflict is heightened by the Corps' lockage regulations, which limit recreational lockages to one for every three commercial lockages. These regulations are subject to interpretation by the lockmaster with widely varying results; conceivably, recreational craft could be required to wait through three double lockages for three complete tows.

Since 1976, the Corps has addressed the problem at L&D 25 by instituting special posted lockage times for recreational craft on weekends from Memorial Day to Labor Day. Between the hours of 9:00-9:45 a.m., 12:00-12:45 p.m. and 7:00-7:45 p.m., only recreational vessels have use of the facility. The 45 minute period allows for one complete lockage cycle, upstream and downstream. This policy has been very successful in reducing conflict because it allows recreational boaters to plan their trips and avoid unexpected delay.

The Corps has also investigated other potential solutions to the recreaional/commercial lockage issue, which were analyzed in the Recreational Craft Locks Study for the Upper Mississippi. These included other regulatory or "soft" measures, such as better public communications, boater education, and queueing or tie-up facilities, and a large number of structural measures, including new locks, floating locks, mobile boat carriers, railway and inclined lifts, and completion of the present auxiliary lock chambers. It is difficult to justify structural measures given the "peak period" nature of recreational/commercial lockage congestion and the great potential for regulatory measures indicated by the success of the posted lockage time program.

4. Description of Secondary Recreation/Navigation Conflicts. There are no identifiable or recognized secondary conflicts in this segment.

5. Description of Complementary Uses. The situation of L&D 26 illustrates the absolute dependency of recreational use of the Mississippi on the Corps' overall activities in flood control and navigation. This is shown by the great discrepancy in recreational use of the river above and below L&D 26; recreation, and in particular, recreational boating, only occurs as a major activity where the Corps has tamed the river. Other than the massive general benefit of the locks, dams, dikes, and other revetments, there are no other specific benefits or complementary uses identified in this region.

(c) Upper Ohio

1. Introduction. The segments investigated here (analytic segments 11 and 16 of the NWS system) are centered on Pittsburgh, Pennsylvania. They are both slack water segments controlled by a series of locks and dams. The Upper Ohio has nine locks and dams along a 265-mile length and the Monongahela has nine locks and dams along a 129-mile length. Both river segments are relatively narrow with industrial and recreational development (marinas) along the banks, particularly near Pittsburgh. The more rural areas along the Monongahela have occasional coal loading facilities and scattered small docks or marinas. The recreation uses include fishing, sailing and motor boating. The Pennsylvania State Fish Commission is developing more boat launching facilities on the Allegheny and Monongahela.

The authorized uses along both rivers are flood control, hydropower, water quality and navigation. The Upper Ohio also has recreation and national defense as authorized uses. Commercial navigation is a dominant use with coal shipments accounting for 70-80% of the movements. Recreation craft are numerous on weekends, particularly near Pittsburgh.

Land use varies along these segments. On the Upper Monongahela the land is predominantly agricultural with occasional coal mines. However, heavy industry appears within ten miles of Pittsburgh and occupies both

banks of the river. Single steel complexes such as United States Steel and Jones and Laughlin take up miles of river bank, with chemical companies and coal-loading facilities in other locations. Railroad tracks run on one or both sides of each segment along almost their entire length. They both constitute major transportation corridors.

Pittsburgh is the dominant urban center in the region with close to two million population, including suburbs. No other towns or cities in the area exceed 50,000. Pittsburgh is an economic, financial and cultural center for the region. It lies at the confluence of three rivers: Monongahela, Allegheny and Ohio.

Employment in the area is primarily industrial with a strong economic base. This is balanced somewhat in Pittsburgh with white collar and service industries.

2. Statement of the Problem. The focus of this case study is on the channel interaction between commercial tows and recreational facilities and craft. This interaction forces the tows to slow down and increases their travel time. Other interactions noted on the segments are land use conflicts between marinas and industrial uses, and fleeting areas occupying recreation river frontage. Benefits are derived for recreational boating and fishing from the creation of pools.

3. Description of the Major Interaction. This interaction takes place wherever marinas are located in or near the channel and the channel is narrow enough so that the tow wake can damage craft moored at the marina or in the channel. This is particularly the case where the channel takes up to most of the river width.

The towboat captains are aware that they are responsible for any damage done by their wake to other craft and shore facilities, such as marinas or craft moored in the marinas. Consequently, they slow down from normal cruising speed (five mph upstream or eight mph downstream) to about half the speed, whenever they approach a marina or a group of recreation craft in the channel. In addition to safety consideratons, the towboat companies are legally liable for damage and can be sued.

The result of tows having to slow down under these conditions means longer travel time and higher costs per ton transported when tows travel at less than optimal

speeds. This negative effect can be mitigated by restrictions on the location of marinas in channels, or by constructing protective breakwaters between marinas and the channel. However, such breakwaters may also be a hazard to navigation. To mitigate impacts on recreation craft in the channel, the most common reaction of the tow companies is not to run tows at the times when the channel is most crowded, such as on weekends.

4. Secondary Interactions. The two secondary interactions noted on the case study segments are mixed land uses and fleeting area needs. These are closely related phenomena. The industrial areas and marinas are "leap frogging" in development along the rivers near Pittsburgh. This means that the uses are causing more interaction in the channel than they might with more separation. This leads to more accidents and creates a less desirable recreation environment.

Fleeting areas on rural stretches of the river or near industrial areas sometimes conflict with recreation sites along the banks. This was a secondary conflict as there were usually adequate recreation sites on the rivers in most areas along the sample segments.

5. Complementary Uses. The main complimentary use noted was in creation of the pools. This construction created areas of river more favorable to both fishing and boating. The beneficial effect is lessoned by the restrictions that locks create for river running types of recreation activity.

(d) Lower Ohio

1. Introduction. The Lower Ohio River in Louisville District consists of 543 miles of channelized river heavily used for commercial navigation. It extends from the junction of the Ohio with the Mississippi at Cairo, Illinois, upriver to roughly 30 miles beyond Cincinnati. The Lower Ohio is controlled with nine high-level locks and dams. The river is characterized by high lift at each lock (20-40 feet) and long pools (60-100 miles), in comparison to older facilities, which involve a larger number of lower and more closely spaced locks and dams.

The Lower Ohio lock and dam facilities have twin lock chambers, 600 and 1,200 feet long, which enables

large tows to be locked through the 1,200 foot chamber in a single pass. McAlpine L&D, at Louisville, has a third 360 foot chamber. L&Ds 51 and 50 are the only remaining unmodernized facilities, having single 600 foot locks. These are to be replaced by Smithland L&D which will have twin 1,200 foot chambers and is presently nearing completion.

These characteristics of the Lower Ohio - multiple locks, widely spaced dams, and long pools - play an important role in determining relationships between recreational and commercial traffic. First, the Lower Ohio has no recreation-derived lock congestion because lockage capacity is so great. Second, the 60-100 mile spacing of locks and dams means that fewer lockages are necessary during a trip of given length.

Finally, the long pools created by the distance between locks and dams have an interesting effect on shore use. Because the pools are so long, their water level is very erratic and unstable downstream of a dam, with the result that recreational and commercial shore facilities (and therefore land use typically are concentrated in the first 20 miles of a pool upstream of a dam. The long pools, therefore, tend to aggravate land use competition in the widest part of each pool. They may also increase the rate of recreational lockages by concentrating users too closely to locks and dams. This possibility has not been investigated by the Louisville District because of the absence of any perceived conflicts.

Another feature of the Lower Ohio is the emergency mooring system for commercial craft, which consists of pairs of heavy 12 foot diameter mooring buoys anchored 580 foot apart along the shore. These buoys are placed throughout the river, particularly just upstream of locks and dams.

The major metropolitan areas along the Lower Ohio are Cincinnati and Louisville. Another town noted by the District as significant in terms of recreational use of the waterway is Evansville. Louisville in particular is an important center for commercial navigation, with a number of loading and fleeting areas and barge-building facilities located just upstream of McAlpine L&D.

2. Statement of the Problem. The major recreation/commercial conflict on the Lower Ohio River concerns competition for river front land in heavily populated and industrial areas such as Louisville. This conflict is exemplified by the issues surrounding the proposed development of the shoreline behind Six Mile Island, in Louisville, as a port and industrial park.

Other recreational conflicts include minor underway conflicts, and conflicts over the improper use of emergency mooring buoys as fleeting moorings, especially where these buoys are placed in areas favored by recreational boaters.

The primary beneficial impact of the navigation system on recreational boating is the overall control and stability of river and shoreline, which makes safe recreational boating and covenient access possible. The recently improved quality of the river is another significant benefit.

3. Description of the Major Conflict. Six Mile Island lies six miles above downtown Louisville, just off the Indiana shore. The island itself is approximately one mile long and less than a quarter mile wide; it is eight miles upstream of the McAlpine Locks and Dams. The channel side of the island has two pairs of emergency mooring buoys along its shore. Just below Six Mile Island, on the Kentucky shore in particular, are a number of marinas, boat clubs, boat docks, and public access areas; further downstream are an even greater concentration of barge ports, fleeting areas, and shipyards.

Six Mile Island is the subject of two conflicts which derive from the fact that the island is a favorite haunt of weekend boaters. The first, lesser problem is that towboat companies improperly use the two sets of emergency mooring buoys on the island for non-emergency fleeting. When barges and tows are left on the moorings over the weekend, boaters find the recreational and aesthetic quality of the island damaged. The same kind of conflict concerning the emergency buoys has occurred throughout the Lower Ohio; occasionally, recreational craft have been guilty of tying up to the buoys as well. Policing of the buoys and the entire channel is the responsibility of the Coast Guard.

The second problem at Six Mile Island concerns a proposal to build the Clark Maritime Center on the Indiana shore behind the island. The final environmental impact statement for this facility concluded that the additional barge traffic created by the new facility would not significantly interfere with recreation since the new port would operate primarily during the workweek, and that the island itself would not be affected by the development. However, the aesthetic and recreational desirability of the area would suffer.

The Clark Maritime Center proposal reflects a direct conflict over shoreline and shore access in an area of concentrated use by both commercial and recreational interests. Commercial operators want and need the facility for economic reasons, while the nearby group of boat clubs and marinas fears that the development will ruin the local environment and damage their facilities with wash created by the added traffic.

Before the proposal for the Clark Maritime Center was developed, commercial use was concentrated further downstream. Now, it will extend beyond the area occupied by the boat clubs. However, despite the controversy, the Clark Maritime Center appears well suited, given the context of a crowded metropolitan river front, because it is more than a mile upriver from the greatest concentration of a recreational facilities and is on the opposite shore, hidden behind Six Mile Island.

Recreational groups also oppose permanent fleeting carried out under permit on channel islands similar to Six Mile Island. This includes fleeting facilities along Twelve Mile Island upstream and along Towhead Island, which flanks the industrial shoreline in downtown Louisville, just above McAlpine L&D.

Louisville District feels that the land use conflicts typified by Six Mile Island and Clark Maritime Center will increase with the growth of commercial and recreational traffic. At present, the District attempts to control such conflicts through its permit granting powers. It may, for example, refuse to issue a port permit if the development would have substantial adverse impact on established recreational uses.

4. Description of Secondary Recreation/Navigation Conflicts. With the exception of the improper use of emergency mooring buoys as feeting facilities, the only secondary conflict on the Lower Ohio involves damage to recreational facilities, the only secondary conflict on the Lower Ohio involves damage to recreational facilities caused by commercial traffic moving at excessively high speeds. Generally, collisions between tows and recreational craft occur only rarely.

One recognized area of recurring conflict is the mouth of the Green River, which flows into the Ohio about 200 miles above Cairo. The Green River is extremely narrow and carries heavy coal barge traffic. Marinas and other recreational facilities at the mouth of the river have been in conflict with towboat traffic over damage to docks and boats. In the recent past, recreational owners have even fired shots at passing towboats to make them slow down. It appears that this approach has been effective.

In general, the District feels that wash problems of this sort are minor anywhere on the river. At the Green River, the issue has resolved itself to a degree by discouraging any increase in recreational traffic.

5. Description of Complementary Uses. The entire navigation system on the Lower Ohio exemplifies the principle of complementary use. In addition to multiple lock chambers, which can be used to separate recreational and commercial traffic during peak weekend times, the large 1,200 foot chambers obviate the time-consuming double lockages that are required for standard tows passing through 600 foot locks. Locks with a 1,200 foot chamber will not now lock through anything that can not be accommodated in a single pass.

The fact that recreational and commercial use are concentrated in the most protected and controlled sections of pools (immediately upstream of a dam) indicates the degree to which these improvements contribute to the potential for large scale recreational boating. Recreational use has also been enhanced by a recent marked improvement in water quality, at least partly due to Corps regulation of shoreline uses, placement of dredge materials, and private landfill operations. Should commercial navigation increase to the point where it has a negative impact on

water quality, recreation uses in the vicinity would again be adversely affected.

(e) Arkansas and Verdigris

1. Introduction. The McClellan-Kerr Navigation System is a large scale project which has extended year round commercial navigation to a region where none existed before. The original economic justification for the project, based on flood control, navigation, and power generation, appears to be equalled or exceeded by benefits in terms of environmental quality and recreation. The system was built between the 1940s and 1970s. It extends northwest along the Arkansas River 400 miles from its junction with the Mississippi River to Muskogee, and then 50 miles up the Verdigris River to the head of navigation at Catoosa, the new port for Tulsa.

The system includes 17 lock and dam facilities (all locks consist of single 110' x 600' chambers), four main stem lakes, and seven upstream or tributary lakes. The upstream lakes were created to trap the naturally heavy sediment load flowing into the Arkansas that would otherwise have filled the navigation channel. These large lakes have vastly improved the environmental quality of the Arkansas and Verdigris region and, with the main stem system, have created a huge recreational potential in an area that ws formerly marginal, dusty farmland.

While commercial navigation has grown to over 10 million tons in 1978, recreation, fish and wildlife users have exceeded project estimates, with over 14 million recreation users at public areas on the navigation channel in 1978 and 27 million when three upstream lakes are included. Annual expenditures of those users are about $160 million, with an estimated investment of $427 million in recreation equipment, for a region whose median annual household income is under $8,000. The combination of recreational and economic opportunities created by the system have, in addition, reversed the long-standing outmigration from the region which began in the 1930s; between 1960 and 1970, the region received a net immigration of about 80,000 persons in response to new employment and recreational opportunities.

The system is a major recreational attraction for both Oklahoma and Arkansas. In Oklahoma, the entire northeast lakes region is popularly known as "Green Country" and is widely publicized as having "more coastline than the Eastern Seaboard of the United States." In Tulsa District, the region is largely rural, with users traveling an average roundtrip of 244 miles (1974) for recreation. Tulsa, Muskogee, and Fort Smith (just across the Arkansas border) are the major urban centers affecting the Tulsa District.

2. Statement of the Problem. Because commercial traffic is not yet heavy, there are as yet no lockage or severe underway conflicts in the system, despite the fact that all 17 locks are single chamber facilities. In addition, boating as an activity ranks behind fishing, sightseeing, camping and picnicking (in that order) in terms of recreational use of the waterway.

The most critical conflict on the system concerns shore land use on the Verdigris River and centers on the use of the environmentally rich oxbows or cutoffs for industrial purposes. At present, the conflict is focused on the request for an oxbow fleeting permit for Port Verdigris Inc., a private commercial port located 13 miles downstream of Catoosa, where State Highway 13 crosses the Verdigris.

3. Description of the Major Conflict. The land kuse conflict over the cutoffs in the Verdigris River is unusual for three reasons. First, the resource of the cutoffs and their benefits to either commercial or recreational activity are purely the result of Corps development. Second, the value of the cutoffs as a resource is increased by the extreme narrowness of the main stem channel of the Verdigris. Third, the conflict poses a real and serious threat to the expansion of commercial navigation along the Verdigris to and from the port of Catoosa.

Half of the 50 navigable miles of the Verdigris between Catoosa and the Arkansas are composed of narrow dug channel, sufficiently wide to allow passage of a 105 foot wide tow, but narrow enough to require the provision of "passing zones" every two and one-half miles to allow simultaneous up- and downstream movement of commercial craft. The channel created 22 cutoffs, formed by the remaining loops of the original river. Twenty of these

have upstream plugs to prevent siltation. These lakes have become fertile pools for fish breeding (flows in the main channel stream are too rapid for this), prized by fishermen, environmentalists, and wildlife groups.

However, these cutoffs have always been regarded by the Corps as ideal sites for fleeting, which is impossible to accommodate on the narrow main stem. Still and protected, the cutoffs could serve the main channel in a fashion analagous to the function of railroad sidings. The Tulsa District owns a narrow strip of land alongside the Verdigris and its cutoffs, and in 1974, it presented a land-use plan for this property, proposing that most shore areas be considered "multipurpose," or usable for industrial purposes by permit if warranted.

The conflict at Highway 33 results from an attempt to increase commercial fleeting capacity on the basis of the plan. Currently, there are only four port facilities on the Verdigris (Catoosa and three private ports) and two fleeting facilities with a total capacity of about 30 barges. The fleeting area shortage is now so great that the turning basin at Catoosa is being used for fleeting. At Highway 33, the private port operator has requested a permit to fleet about 75 barges in the small oxbow immediately upriver, to replace a smaller facility four miles (and two hours) away. The shuttling of barges to and from this existing facility is too costly in terms of fuel. The new fleeting facility would consist of 21 postholes -- steel columns buried in the shore with attached mooring cables. The facility would require no shore access, but barges could cover up to two-thirds of the cutoff's surface.

At two public hearings on the Highway 33 permit, the issue has been hotly contested. Environmental and recreational interests, including the United States Fish and Wildlife Service, the Oklahoma Department of Wildlife Conservation, the Sierra Club, the Audubon Society, and a local private club want all cutoffs reserved for non-industrial use. The fleeting facility itself appears to be a minor issue. Commercial interests are equally intransigent and want to allow industrial development in all cutoffs to promote navigation expansion. Since the District can only respond on the basis of its limited permit-issuing powers on a project-by-project basis, the issue is not deadlocked. The District has prepared an EIS

on the Highway 33 proposal, which will undergo public review and Corps action at the Division or National level.

The implications for commercial navigation are serious, in view of the present fleeting capacity shortage. Coal loading, for example, is carried on continuously and requires a large immediate reserve of empty barges; therefore, if rich eastern Oklahoma coal resources are mined, the waterway system will be unable to respond because of insufficient fleeting capacity.

Alternatives to fleeting in oxbow lakes are expensive and may have far more serious environmental consequences than the facilities proposed for Highway 33. For example, fleeting could be accommodated by extensive dredged areas at Catoosa or by using the wide Arkansas where it is joined by the Verdigris. The latter solution would involve continuous 100 mile round trip shuttling to Catoosa. The additional traffic from this activity could require widening of the Verdigris River.

4. Description of Secondary Conflicts. Since lakes on the Arkansas-Verdigris system receive the greatest visitation, and the Verdigris channel public access areas are remote from major population centers, there are no major underway or channel conflicts. Since fishing is a more important activity than boating alone, users typically travel from a boat ramp to a secluded spot (such as a cutoff), thereby avoiding commercial traffic. In addition, the speed and scour of the channel, particularly the narrow Verdigris main stem, is not good for fish breeding or fishing.

A minor conflict has occurred during the hunting season on the waterway, where occasionally hunters have inadvertently punctured towboat pilothouses and barges instead of deer.

5. Complementary Uses. In addition to the overall benefits of the navigation system to recreation and improved environmental quality, there are a number of specific examples of complementary use on the McClellan-Kerr System.

One example the District's continual and presently successful program to limit the spread of Eurasian

Watermillfall, a noxious aquatic plant which has threatened to choke up sections of the waterway, and which, unchecked, has caused much damage elsewhere in the United States. The spread of the plant was controlled before it affected commercial navitation, but not before public access areas were closed off. Recreational users, particularly fishermen, were opposed to the program because they misunderstood the threat posed by the plant; they found the plant good for fish habitats, did not realize the District was only controlling (and not eliminating) it, and did not appreciate that the plant would close off recreational access if unchecked. However, in fact the plant control program has provided benefits to recreation as well as to commercial navigation.

A second specific example is that as a result of improved environmental quality, the Robert S. Kerr Reservoir (mainstream) has attracted Bald Eagles, which are endangered species. The new habitats are quite important environmentally, and conflicts may arise in the future over the need to protect nesting sites from both commercial wave action and recreational activity.

(f) Columbia River

1. Introduction. Analytic Segment 52, the Lower Columbia, is a 145.5 mile stretch of the Columbia River from Bonneville Dam, 40 miles east of Portland, to its mouth at the Pacific Ocean. Also included in this segment is about 100 miles of the Willamette River from just outside of Salem, Oregon to its mouth at the Columbia River at Portland, Oregon. Segment 51, the Upper Columbia/Snake Rivers, extends 179 miles from mile 145.5 at Bonneville Dam along the Columbia River to the mouth of the Snake River, and from the mouth of the Snake, 140 miles upstream to Lewistown, Idaho.

These channelized rivers are used for navigation, recreation, water quality and flood control, and a variety of commercial activities such as fishing, irrigation, urban and industrial use and power generation. Facilities in this region include locks, dams, reservoirs, ports, levees, numerous moorage and house boat facilities, and general recreational facilities located all along the waterways. Seaports capable of accommodating deep-draft, ocean-going vessels located on the river include Astoria,

Oregon; Longview, Washington; St. Helens, Oregon; Portland, Oregon; Vancouver, Washington; and Camas-Washougal, Washington.

Commercial navigation is quite heavy on the Columbia. Oceangoing vessels use the waterway as far upstream as Portland and Vancouver. Barging and log rafting operations alone account for several million tons of traffic a year through the locks at Bonneville. Commercial traffic along these segments consists primarily of grain products and rafted logs going downstream, and fertilizers and petroleum products going upstream. Traffic volumes are fairly consistent from month to month.

Recreational use includes all types of water-related and water-enhanced recreational activity. Sightseeing constitutes the highest participation percentage although visitors often engage in boating, fishing, picnicking, camping, and swimming. Most of these activities occur during the summer months. Most of the recreation demand for the region comes from the Portland-Vancouver metropolitan area, and the Tri-Cities (Richland, Pasco and Kennewick, Washington) area. In addition, the Lower Columbia serves as a major tourist attraction for the Pacific Northwest, bringing millions of tourists into the region.

Urban land use along the Lower Columbia includes the Portland-Vancouver area and numerous small communities downstream. The remaining area is taken up by farms, undeveloped rural areas, industrial and commercial developments. Of the over 1,500,000 people that live along the Lower Columbia, most are located between the frontage from St. Helens, Oregon to Camas-Washougal, Washington, within fifteen miles of the Portland-Vancouver metropolitan area.

The Upper Columbia/Snake River Segment is sparsely populated. Dryland and irrigated farming together with some livestock operations are the major activities of the area. Railroads and highways run along both banks of the Columbia and Snake, limiting access to water frontage. Commercial navigation deals primarily with the transport of grain and fertilizer, although in the lower portion of the segment along Lake Bonneville, small communities are also supported by the timber industry. The Tri-Cities area near the confluence of the Snake, Yakima, and Columbia River is a highly developed urban-surburban community

with a population of about 100,000. A variety of activities from river commerce to atomic energy development are found there.

2. Statement of the Problem. The most significant recreation-navigation conflict on the Columbia/Snake River is congestion between recreational boating and commercial traffic. However, other water uses conflict with each other more than do recreational boating and navigation.

Recreation-navigation conflict manifests itself in three areas: the Portland-Vancouver metropolitan area, the Tri-Cities area, and to a lesser extent, at Bonneville Lock and Dam. These conflicts are associated with proximity of recreational and commercial port facilities, high traffic volumes, and delays in both commercial and recreational lockage times.

Other conflicts on the segment are often more severe than recreation-navigation conflicts. The most significant is the impact of hydropower generation on a variety of other uses, including recreation, navigation, environmental protection, and other instream and consumptive uses. Many of these conflicts result from surges released at peak power demand periods. Additional conflicts include those between commercial fishermen, sports fishermen, Native Americans, environmentalists and other regarding preservation and use of the river salmon resource. Commercial navigation is one of the least conflict-generating uses on the Columbia/Snake Rivers.

3. Description of the Major Conflict. The conflict between navigation and recreational boating results from general overcrowding and certain physical parameters. At Portland-Vancouver, congestion is most severe along the Willamette River from mile 30 to its mouth, and on the Columbia from mile 95 to 135. These areas are heavily traveled by tugs and barges, and in the case of the Columbia, by deep draft ocean-going vessels. In addition, large marinas are located at many points in these areas and associated recreational boating is heavy. Channel configurations and to a lesser extent marina locations have added to the problem. The mouth of the Willamette is narrow. Hayden and Government Islands limit water space on the river and experience heavy recreation use. Marinas located in the vicinity of turning basins at

miles 105 and 106 on the Columbia also help to create congestion in the area.

The Tri-Cities region, like Portland-Vancouver, receives heavy recreational use, exceeding four million visitors annually. Power boating is extremely popular, averaging more than 600,000 boating occasions a year. The most outstanding boating event is an annual week-long series of unlimited hydroplane races, usually held in July. This heavy recreational use not only conflicts spatially on the river with commercial navigation, but also competes for lockage time at the Ice Harbor Locks. At times, groups of recreational craft going up to the Snake River will be locked ahead of commercial vessels.

At Pasco, the Port Authority has purchased docking space for port expansion in an area informally used and tentatively planned for recreation. This conflict reflects the growing demand for both commercial and recreational facilities in the area.

At Bonneville, a number of factors are involved in the congestion problem. First, Bonneville is the smallest lock in the Columbia River, half the size of all other locks in the system. As a result, tows must be broken up to pass through the locks. This intermittent commercial congestion is compounded by heavy recreational boating activity on and below Lake Bonneville. Further, the channel configuration approaching the lock from below the dam is such that at times of heavy flows from peak power generation, the velocity of the river precludes safe passage of recreational craft and of lower horsepower tugs. The conflicts between navigation and recreation are, however, minor when compared to the impact of hydropower surges on boating, swimming, and use of island and river shores.

4. Secondary Navigation-Recreation Conflicts. Besides the problems of congestion in specific areas on the Columbia/Snake other minor recreation-navigation conflicts occur. These conflicts are site specific or are attributable to conditions that prevail on unique occasions. For example, when dredging the Lower Columbia River channel, particularly near the Portland-Vancouver metropolitan area and the river mouth, the movement of recreational craft on the river is restricted temporarily to clear the way for dredges.

In the Portland-Vancouver area, there is also a problem with providing adequate public access to the river. This problem will become more serious as surrounding areas grow and demand for access is increased.

Another conflict relates to the wakes of barges traveling up or down river. Wakes erode beach shorelines, including certain archaeological sites along the river, and adversely affect marinas. However, attributing wave action and erosion solely to commercial craft is not possible, as recreational craft, natural wind action and hydropower releases in many instances contribute to these problems and are often more significant than commercial navigation in causing them.

In the Tri-Cities area, the annual hydroplane races require a full, stable lake level during the week of the event for safety and effectiveness. Normally, these conditions are met without major impacts on other uses. In 1977, a record drought year, low flow conditions caused cancellation of the races.

Another commercial activity that may conflict with recreation is the logging traffic. Occasional "deadheads" broken off from log rafts may get caught in pools near lock openings or in bays and impede recreational boating. The Willamette is completely closed at certain times of the year as the result of logging activity. Log rafts literally clog the river and preclude all other forms of navigation.

5. Complementary Uses. Navigation has had a beneficial effect on recreation on the Columbia/Snake in that it has been one of the authorized uses which created recreational areas. All of the lakes formed by locks and dams for navigation purposes have provided environments and access for a variety of recreational activities. Lakes Bonneville, Wallula (McNary), and Sacajawea (Ice Harbor) all experience extremely heavy recreation use.

(g) San Francisco Bay

1. Introduction. The San Francisco Bay Region is a series of connecting bays beginning at the confluence of the Sacramento and San Joaquin Rivers near Pittsburg, California (Suisun Bay), extending west through the

Carquinez Strait to Marin County, California (San Pablo Bay), then south to Santa Clara County (south San Francisco Bay). This estuary has an area of approximately 435 miles and a shoreline of about 275 miles at mean sea level. The San Francisco Bay Region host the busiest ports in the nation, handling more than 50 million short tons of cargo a year. Located at various points along the bay, these ports include San Francisco, Redwood City, Oakland, Richmond, and port facilities in the east San Pablo Bay, Carquinez Strait and Mare Island Strait areas near Benicia.

San Francisco is located on the northern end of a peninsula which separates the southern part of San Francisco Bay from the Pacific Ocean. The principal waterfront facilities of the port extend from Black Point on the north side around to India Basin on the east side of the peninsula, a distance of almost six and one half miles. San Francisco is primarily a general cargo port, handling automobiles, bulk liquids, newsprint, grain, cotton, and copra, among other commodities.

Redwood City Harbor is located on the west side of the south San Francisco Bay, about 20 miles south of San Francisco. The harbor consists of a channel and two turning basins and covers 182 acres. The chief products handled by the port are cement, gypsum, salt, and petroleum products.

The Port of Oakland is located on the eastern shore of the Central Bay, opposite San Francisco. Port waterfront facilities extend from the Outer Harbor, located immediately south of the San Francisco-Oakland Bay Bridge, to the Inner Harbor facility located along the Tidal Canal connecting the Oakland-Alameda Estuary with San Leandro Bay. Total channel length in this estuary is eight and one half miles. Oakland receives all types of cargo, handles a great deal of containerized and barge-bulk cargo, but also handles assorted special commodities. Oakland handles in excess of 7,000,000 short tons of cargo a year.

The Port of Richmond is located on the eastern shore of the Central Bay, nine miles northeast of the Golden Gate Bridge. The port area includes five miles of outer harbor between Point San Pablo and Point Richmond and the inner harbor extending from Point Richmond to Point Potnero and the inner end of the Santa Fe Channel, a

distance of four additional miles. Richmond handles primarily petroleum, but also handle dry bulk and liquid bulk cargoes.

Ports located on the southeastern shore of San Pablo Bay, the southern shore of the Carquinez Strait and both shores of Mare Island Strait (with the exception of the Port of Benicia) all serve specific industries. Oil is the primary cargo, but sugar and other specialized cargoes are also handled.

Commercial use of the Bay Region is year round and very heavy. In 1973, over 70,000 cargo and commercial passenger vessel trips were made to Bay ports, and an additional 400 vessel trips were made through the Bay area to the ports of Sacramento and Stockton. Recreation use is also year round and intensive, with heaviest use on holidays and weekends.

Recreational use includes a variety of activities, the most significant being sightseeing and boating. Water contact sports, although enjoyed, are not a significant use due to cold water temperatures and general windy, choppy weather conditions. Boating use tends to favor sailing as opposed to power boating, for similar reasons, and is heaviest in the Central Bay. Over 100,000 recreational boats were registered in 1979 by the State of California in the nine counties surrounding the Bay.

Sightseeing is heaviest on the western side of the Bay. San Francisco attracts many tourists and the Marin Peninsula is heavily used due to excellent park facilities. Wildlife refuges are located in the far southern part of the Bay and along Suisun Bay.

Land use along the bay is decidely urban in nature. The Bay Region is estimated to have five and one half million people. Urban use extends all along the South and Central Bay, with the exception of large areas of salt evaporators and wind sloughs along the Southern Bay south of Redwood City around to the west side of the Bay, north to the San Mateo-Hayward Bridge. San Pablo Bay is largely marshland, as is Suisan Bay except at specific areas where port facilities and associated commercial use have become prominent.

Employment in the nine counties surrounding the Bay is concentrated in services, trade, manufacturing and

government. Services is the most rapidly growing sector, reflecting the rising importance of the tourist industry. Government is also a major growth area. Average household income in 1970 was approximately $13,000 and in certain counties (Marin and San Mateo) was appreciably higher. The Bay area therefore represents a large effective demand for recreational facilities.

2. Statement of the Problem. Although the San Francisco Bay covers a vast area, much of the Bay is not navigable by commercial or recreational vessels. About half of the Southern Bay and Suisan Bay are less than six feet deep. Close to 70% of San Pablo Bay is less than six feet deep, and of that, over half is less than three feet deep. The area that remains is the subject of two major conflicts which are a direct result of these conditions and the intensity of use. These include congestion between recreational boating and commercial navigation and the impacts of dredging Bay channels for both navigation and recreation purposes.

3. Description of Major Conflicts. Congestion in the Bay is readily observable. The volume of traffic on any weekend in the Central Bay, the numerous plans for port extension, and the waiting lists at marinas (some eight years long) all testify to unsatisfied demand for space. This conflict not only manifests itself in shipping channels and water surface, but on shore access sites and in harbor areas. The two primary areas of conflict are in the Central Bay and in all commercial harbors.

Every oceangoing vessel that enters or leaves any of the ports in the Delta Region or the Bay Region must come through the Central Bay. The three busiest commercial ports in the Bay (San Francisco, Oakland, and Richmond) are located about ten miles apart on the southwest, southeast and northeast portions of the Central Bay, respectively. At the same time, the area is a scenic, highly valued recreational resource. The area's largest and most heavily used marinas are located along the eastern shore of the Bay from San Leandro to Berkeley, along the northeastern shore from the San Pablo Point to Richmond, along the west side of the Bay at various locations in Marin County, and in San Francisco. The Central Bay area even has an Island State Park located near its center, just off the main commercial navigation channel.

As a consequence, volumes of both recreational and commercial traffic are extremely high. Shipping lanes converge upon heavily used recreation areas. Weekly sailboat races cross shipping channels. These conditions inevitably create navigation-recreation conflicts.

The congestion problem is severe everywhere on the Central Bay, but the worst areas are the triangular region from the Golden Gate Bridge to Angel Island State Park and Yerba Buena Island; between the Port of Oakland and San Francisco; and between Richmond and San Rafael. In addition to congestion in the Central Bay, conflicts occur in all harbor areas on the Bay. These conflicts involve both traffic conflicts and land use conflicts.

At Oakland, large marina facilities have been constructed in the old commercial berths near Government Island and the Brooklyn Street, at the far end of the inner Harbor over Park Street, Fruitvale Avenue and High Street as well as the bridge on Dennison Street preclude unrestricted passage to San Leandro Bay at the south end of the harbor. As a consequence, recreational craft travel down the narrow main channels, and out into the Bay. The location of marinas and the effective funneling of recreational traffic through commercial lanes creates the most serious harbor congestion problem in the Bay Region.

Richmond Harbor has a similar problem. Present port expansion plans call for the extension of facilities so that an existing marina will be located at the far side of a turning basin. The effect of the proposed expansion would be that every recreational craft leaving the marina would pass through the turning basin, a circumstance that would inevitably lead to conflicts between the two activities.

At Alameda, an extension of the Port of Oakland on Government Island, a proposed switch between a marina area and a port area is being evaluated. These site changes are designed to allow for further port expansion at the expense of marina expansion and exemplify the land use conflicts that exist in other ports. Congestion on the water is also a problem.

Marinas are located at both ends of Carquinez Strait. Recreational craft going to and from Suisun and San Pablo Bays pass through straits which are lined with

wharfs and large commercial vessels. The congestion conflict is apparent everywhere in this area, especially at the Carquinez Bridge and at Mare Island. Mare Island marinas are also located at the end of the Mare Island channel, resulting in the funneling of recreational craft through commercial areas.

San Francisco Harbor does not have an inner harbor or a channelized configuration. However, the three marinas are all located next to shipping lanes used by commercial vessels. All of these areas are congested and experience conflicts.

Redwood City Harbor is unique in that it is primarily a recreation harbor. Commercial activity, although significant, is not as important as recreational use. Further marina expansion is anticipated. Nonetheless, boats at the large Municipal Marina pass through two turning basins and by a number of commercial wharfs in order to gain access to the Bay.

Dredging to maintain navigation channels is another major recreation-navigation interaction. Unlike the congestion conflict, dredging has beneficial as well as negative effects on recreation. In fact, recreational boating requires dredging at specific marina locations.

The average annual removal of bottom sediments ranges from five to ten million cubic yards a year and averages 8,745,000 cubic yards. This includes all Corps and Corps-permitted activity. Of this total, 43% is dredged to keep channels open for use by the United States Navy, 56% to maintain deep water channels for commercial shippers, and one percent for use of the Army, Coast Guard, and recreational boaters. Some channels are dredged as frequently as twice a year, others only once in 12 to 16 years.

The negative impacts of dredging fall into two catgories: the effects of dredging itself, and the effects of disposal of dredged material. The two areas affected by dredging related to recreational use and enjoyment are aesthetics and the environment. Highly turbid conditions associated with dredging are considered unappealing to boaters. As this condition is temporary, it is not considered a serious problem. However, dredging significantly affects the environment, which also affects aesthetics and recreational potential.

The environmental effects of Bay dredging are biological and chemical in nature. Biologically, dredging affects the entire Bay ecosystem. Plants, plankton, shellfish, fish and other organisms are impacted. The basic effects on life have been to reduce the variety of species and to reduce in numbers the surviving species. Areas dredged do not recover in terms of reestablishing an ecological community similar to the one that existed prior to dredging.

Chemical effects of dredging include release of trace contaminants and nutrients, which directly affect water quality and dissolved oxygen levels in the water. Both have further biological impacts, such as the reduction of plankton and fish populations. These impacts decrease the aesthetic appeal of the Bay and reduce recreational opportunities such as fishing. More importantly, they affect the entire Bay ecosystem. The loss of the natural environment ultimately affects the quality of the recreational experience.

The effects of dredged material disposal depend partly on whether disposal is carried out on land or in Bay waters. Water disposal impacts are similar to dredging impacts except that they are more secure. Land disposal, however, may have further negative consequences.

Many of the areas where land disposal is taking place or is proposed for the future are areas where the natural environment is a more important recreational resource. Near Redwood City, for example, one site for dredged material disposal is located near a wildlife refuge. The same applies to the Suisun Slough disposal site. Disposal sites at San Leandro and San Rafael are in areas used primarily for recreation. There is a need for additional sites for dredge disposal, as present sites have been used to their capacities.

4. Secondary Recreation-Navigation Interactions. Minor conflicts between navigation and recreation are more site specific. They include erosion of marina and residential shoreline by wash from the ferries that travel from San Rafael to San Francisco and the presence of a "mothball fleet" in Suisun Bay. The erosion problem has been addressed by reducing ferry speeds. The "mothball fleet," about twenty World War II vintage warships, impede recreational use on the Suisun Bay, but present a relatively minor problem.

5. Complementary Use. Beneficial impacts attributable to dredging include facilitating recreational boating in certain areas and keeping marinas in operation. The San Rafael Creek area is planned as a predominantly water-oriented, open space recreational area. A dozen marinas are located here, none of which would be viable were it not for the Corps dredging a channel from the marina areas to deeper bay waters. At San Leandro the entire waterfront area within city limits has been designated for recreational use. The San Leandro Marina requires continual dredging of a channel to allow access to deep bay water.

In addition to access channel dredging, all marinas on the Bay periodically require dredging permits from the Corps to maintain marina areas. Maintenance dredging is necessary every 5 to 10 years.

(h) Florida Coast

1. Introduction. The Atlantic Coast of Florida extends the Florida-Goergia line to the Florida Keys, a distance of more than 500 miles. It consists of a series of sandy barrier islands, broken at various points by inlets. The barrier islands, generally backed by low tidal marsh or lagoon, separate the mainland from the Atlantic Ocean. The Atlantic Intracoastal Waterway extends all the way along this coast and, for the most part, is located between the barrier islands and marshland. This sheltered inland channel serves commercial barges, commercial fishing boats and recreational craft. The majority of the waterway from Jacksonville to Fort Pierce has depths equal to or in excess of its authorized 12-foot depth, while depths from Fort Pierce to Miami are generally greater than the 10 foot project depth. At its narrowest points, the waterway is 125 feet wide.

Fixed bridges over the waterway provide a minimum vertical clearance of 65 feet at mean high tide and a horizontal clearance of 90 feet between fenders. There are also numerous drawbridges across the waterway.

Deep water ports along the waterway from north to south include Fernandina Beach, Jacksonville, St. Augustine, New Smyrna, Port Canaveral, Fort Pierce, Palm Beach, Port Everglades, and Miami. All ports have drafts of 27 feet or more except for New Smyrna and St. Augustine.

Residual fuel oil for electrical generating plants is the major commodity transported along the waterway. These barge movements generally originate at a deep water port and are shipped to power plants at various points on the Intracoastal Waterway. Other products, coming from Gulf States, include distillates, tar and asphalt. Other significant movements include sugar, sodium hydroxide, metal products (machinery and electrical equipment), steel and iron scrap, fish and nonmetallic mineral products.

Recreational use along the waterway includes boating and swimming. Boating is heaviest from the end of March to the beginning of June and from the end of August to the end of December. Yachts traveling to and from North Atlantic harbors, as well as smaller motorized and non-motorized boats of local origin, comprise a good deal of this traffic. Local traffic is highest near metropolitan areas and at points of access. Tourist traffic consists in most cases of larger vessels migrating seasonally to various points along the waterway, traveling as far as Miami and the Caribbean and returning in the summer to ports in the north.

Swimming occurs all year around, but has seasonal peaks. From Cocoa Beach north, about 75% of the beach use occurs during the summer. South of Vero Beach, 65 to 70% of beach use is in the winter.

Land use along the waterway varies from the intensely urban development in Miami to the undeveloped land between St. Augustine and Jacksonville. About 150 miles of the coast, from Miami to West Palm Beach, is urban. This area includes the Fort Lauderdale and Boca Raton areas. Other major urban areas are Jacksonville, St. Augustine, the Daytona Beach area, the Titusville-Merritt Island-Melbourne area, and the Fort Pierce area. The remainder of the coast is fairly undeveloped.

A large percentage of the labor force is engaged in housing and tourist related industries. An estimated 25 million tourists enter Florida a year and spend four billion dollars annually. Tourist activity is concentrated in coastal areas. The state is also experiencing rapid population growth. From 1960 to 1970, Florida's population increased 37%, and a similar rate is expected in the future. Most of this increase will probably occur in coastal areas.

2. Statement of the Problem. The Atlantic Coast of Florida, besides being a commercial artery, is a highly valued, highly utilized recreational resource. The major direct conflict between commercial navigation activities and recreational boating activities is the congestion caused by the presence of both types of craft on the waterway. Commercial use of the waterway was close to 40,000 vessel trips between Miami and Jacksonville and 26,000 vessel trips between Miami and Key West in 1977. Recreational use of the waterway vastly exceeds commercial use. Further, some commercial vessels are engaged in tourist related, recreational activities such as sport fishing. The volume of traffic handled by the generally narrow channel, compounded by bottlenecks at bridges, often creates congested conditions. Nine commercial/recreational collisions in 1977 and six 1978 provide further evidence of conflicts between the two uses.

Other problems on the Florida Coast related to recreation and navigation have to do with erosion caused by vessel wakes and institutional planning constraints which set navigation and recreational use planning at odds with each other.

3. Description of the Major Conflict. Congestion between commercial and recreational traffic occurs throughout the Florida portion of the Atlantic Intracoastal Waterway. Significant factors associated with congestion are proximity to moveable bridges and the width or narrowness of the channel. As a general rule, the more factors that come into play in a given area, the more serious is the congestion problem.

For example, Fort Lauderdale, located in the center of an urbanized coastal strip in Broward County, handles a great deal of commercial and recreational traffic on its section of waterway. The width of the commercially and recreationally usable channel, in conjunction with the traffic volumes generated by the urban area, creates congested conditions. Bridges span the waterway at numerous points and impede traffic, which contributes further to the congested conditions.

At St. Lucie Inlet, congestion is severe due to the area's attraction as a recreational area. The urban areas of West Paulm Beach and Fort Pierce are located to the South and North, and the Okeechobee Waterway, via the St. Lucie Canal, connects with the Atlantic at this point.

Two moveable bridges, the Hutchinson Island Bridge and the Jensen Bridge, span the waterway immediately to the north. Periodically, these areas experience lines of vessels waiting for bridge openings to allow passage.

4. Secondary Conflicts. The most significant secondary conflict deals with institutional constraints which set navigation and recreation planning at odds with each other, particularly as far as the Corps of Engineers is concerned. Initially, when the waterway was authorized and constructed, future recreational activity was not taken into consideration. Since that time, recreational use has in part replaced navigation as one of the major activities on the waterway.

Planning for facilities to meet the growing recreational demand has become difficult to implement, as activities of this kind must relate to initial project purposes. Similarly, where non-federal agencies attempt to respond to recreational demand, they are hindered by other administrative policies. Initially, lands adjacent to federally operated projects could be developed for recreation on a 50-50 cost sharing basis. Often, state agencies, counties or cities in Florida would contribute land as equity in this cost sharing relationship. The land would then be dedicated for 25 to 50 years for that limited use, and the Federal Government would produce facilities. New interpretations of laws pertaining to this procedure limit this arrangement to reservoirs and further state land may not be used as collateral in this arrangement. These policies have put a damper on recreational development of presently underused areas along the waterway.

Another issue which affects both navigation and recreation has to do with the wakes generated by the vessels in narrow channels. In the Palm Valley area north of St. Augustine, erosion of private property by wakes has become so severe that speed limits have been put into effect. Although recreational boats are primarily responsible for the erosion, all vessels, including commercial craft, have had to reduce their speeds.

5. Complementary Uses. One activity required for navigation on the Inland Waterway that directly benefits recreation is dredging. Dredging not only keeps channels and inlets open to deeper draft recreational vessels, but also benefits beach users when dredged material is

used for beach maintenance and creation on eroded shorelines. Further, islands created by dredge disposal have become highly valued wildlife refuges at many places along the coast.

Dredging takes place at various points on the waterway, primarily at areas in the vicinity of inlets where strong tidal flows bring suspended sand inside bay systems, which are then precipitated to the bottom as tidal velocities decrease. Other major shoaling areas are at nodal points midway between inlets and along sharp bends in the waterway. In these areas, the water is slow moving or still and fine sand and silty sediment are precipitated to the bottom. The major shoaling areas are found at St. Augustine Inlet, Matanzoa Inlet, in the Titusville area, at Canaveral Harbor, at Melbourne, Fort Pierce, St. Lucie Inlet, Jupiter Inlet, the area from Lake Worth to Boca Raton in the Fort Lauderdale-Hollywood area, and at Virginia Key and Key Biscayne.

Beach erosion is found all along the coast, but is most serious at many places near dredging sites. Beach rejuvenation is possible when the quality of dredged material is suitable for that purpose and when beach disposal is cost effective. The State of Florida has recently enacted legislation allowing the state to pay the difference between disposal in the least costly area and disposal in a nearby beach area, and making such disposal mandatory when feasible. Only 25-35% of dredged material is suitable for such purposes; the remainder must be disposed at dredged material island or land sites.

Beach creation or replenishment due to dredged material disposal has been realized to the south of Jacksonville Harbor, at various places along Brevard County, at Fort Pierce, at Palm Beach County from the Martin County line to Lake Worth Inlet, and from South Lake Worth Inlet to the Broward County line, all along Broward County, and in Dade County from the Broward County line to Cape Florida.

Another beneficial effect is that dredged material islands in many instances have become wildlife refuges. The Corps has been prohibited from disposing further material not suitable for beach building in these areas and is not allowed to create new areas because of environmental concerns. In 1979, only two emergency dredging operations, at Cape Canaveral and St. Lucie

Inlet, took place due to problems in conforming to the Clean Water Act of 1977 and because of delays and difficulties in obtaining permits. New disposal sites are becoming increasingly difficult to locate.

(i) Chesapeake Bay

1. Introduction. The Chesapeake Bay and its tributaries constitute most of analytic Segment 41, with the exception of the Atlantic Coastline from Cape Charles, Virginia to Cape May, New Jersey and the Delaware Bay. The coastline on this segment, although it has high levels of recreation use, has little commercial navigation activity and no recreation/navigation conflicts. The Delaware Bay, though heavily used by commercial vessels bound for the ports of Wilmington, Delaware and Philadelphia, Pennsylvania, is little used as a recreation area due to heavy pollution and other aesthetically undesirable factors. Chesapeake Bay is used heavily both by recreational boaters and by commercial vessels bound for Baltimore and passage through the Chesapeake-Delaware Canal.

The Chesapeake Bay and its tributaries constitute the largest estuarine system in the United States and one of the largest in the world. The Susquehanna River, which provides 50% of the estuary's fresh water supply, enters at the northern head of the Bay. Major western shore tributaries include the Potomac, Rappahannock, James, Patuxent and York Rivers, which cross the broad tidal basin of the Bay. The eastern shore of the Bay, also known as the Delmarva Peninsula, is cross-cut by many smaller tributary rivers. The tidal shoreline of the Bay is about 7,325 miles in length and has a surface area of about 4,440 square miles.

The Bay is used for all types of recreational activity, including boating, swimming, fishing, and water enhanced shore activities such as camping and picnicking. Recreation demand on the Bay vastly exceeds the supply of facilities in every category except water surface area, and in every area on the Bay.

Commercial navigation principally involves deep draft vessels, but also includes other vessel types. Major ports include Baltimore, Maryland, with a 42-foot channel, and the Norfolk-Hampton-Newport News area in Virginia, with a 45-foot channel. Waterborne commerce in the region exceeds 110 million tons annually.

With the exception of the Baltimore/Washington and Norfolk/Hampton/Newport News metropolitan areas, the Chesapeake shore is primarily rural in nature. Incomes, particularly in the Washington area, are high relative to other eastern metropolitan areas.

2. Statement of the Problem. The major conflict between commercial navigation and recreation is the problem of boating congestion at specific locations on the Bay. Although there is an overwhelming surplus of available water surface to meet commercial and recreational boating demands, limited access causes recreational boating traffic to concentrate in certain areas. The problem, therefore, is not supply of water surface but the shortage of marina slips and ramps that give access to the Bay and its tributaries.

Other conflicts include problems associated with the potential effects of salt water intrusion as a result of dredging commercial channels, and the environmental effects of waste from commercial vessels passing through the waters of the Bay.

3. Description of the Major Conflict. There are over 300 marinas on the Maryland portion of the Bay. The majority are located on the upper portion of the Bay in Anne Arundel, Baltimore and Cecil Counties. Conflicts occur in the Annapolis area at the mouth of the South River, the Severn River and the Magothy River. Around Baltimore, congestion occurs at the mouth of the Patapsco River, the Black River and Middle River. At the Chesapeake-Delaware Canal, the mouth of the Elk River is congested. In Virginia, congestion is concentrated around the Norfolk-Hampton-Newport News area.

The attributes associated with these conflicts are proximity to urban areas with high recreation demand and limited public access on other parts of the Bay. In addition, all of the areas are situated at narrow inlets or the extension of river mouths, which constricts the available water surface area.

4. Secondary Conflicts. Salt water intrusion partially attributable to dredging for commercial navigation may indirectly cause problems to swimmers. High salt water concentrations allow stinging sea nettle to extend their habitat to northern parts of the Bay. Nettles, closely related to combjellies, reach their

peak abundance in summer months and discourage swimming and other water contact activities. Barriers have been placed in the water at some beach locations to allow safe swimming. Proposed deepening of the Baltimore harbor channel may increase this problem, particularly in low runoff years.

Pollution, partly attributable to commercial navigation, poses a severe threat to water quality and the desirability of the Bay as a recreational resource. It is estimated that the raw sewage discharged into the Bay by ships in transit is equivalent to that of a community of twenty-five thousand people. This consideration is particularly significant when one notes that the Delaware Bay in the same region is not used as a recreational resource due to pollution.

(j) Lake Superior

1. Introduction. Western Lake Superior encompasses a four county area of Minnesota, a four county area of Wisconsin, part of Michigan, and the major metropolitan area of Duluth-Superior, which had a population of 345,000 in 1970. Large volumes of commercial traffic are generated in Western Lake superior, primarily from the harbors of Duluth-Superior, Two Harbors, Taconite, and Silver Bays. Large ships, such as ore carriers, move directly between these harbors to other Great Lake ports through the Soo Locks linking the eastern end of Lake Superior with Lake Michigan. Aside from these commercial harbors, access to Western Lake Superior is generally poor, particularly on the northern coast; as a result, recreational use of the lake is relatively low.

There is a growing demand for access facilities, and the St. Paul District is currently planning the construction of several small craft harbors at Grand Portage and Lake City in Minnesota, Ashland and Washburn in Wisconsin, and Little Girls Point in Michigan. The District has already completed a number of recreational harbors, including Cornucopia Harbor, Banfield Harbor, Point Wing Harbor, and Saxon Harbor in Wisconsin, and is carrying out similar projects in Minnesota at Lutsen Harbor, Knife River Harbor, and Beaver Bay Harbor.

Because of the great size of Lake Superior, the shortage of recreational facilities and access points, and

the concentration of commercial traffic in a few harbors and along major navigation routes, there are no recognized conflicts between commercial and recreational use on the Lake. It is probable that there are minor channel conflicts in Duluth and other heavily used commercial harbors.

2. Description of Potential Conflict. Lake Superior was selected as a case study because some sources have indicated that future water withdrawals in the Great Lakes basin could cause a major drop in lake levels. This process would occur gradually over a long period of time, on the order of thirty to fifty years. Present shore-based recreational uses would certainly be affected. However, it is felt by the Corps that the time period involved is more than adequate to allow gradual adjustment by the owners of shore property and the operators of shore-based recreational facilities to the receding shoreline. No major impacts are expected and, therefore, no mitigating measures are planned.

The reduction in water surface space that would be generated by this change is insignificant in comparison to the total area available for both recreational and commercial uses. The ecology of the shoreline should be able to adapt to slowly changing water levels, so that vegetation and wildlife would be little affected overall. A strip of new land would come into being along the shoreline which, the controlled development, could provide additional public access and recreational opportunities.

Even a very substantial increase in commercial traffic on Lake Superior, combined with a drop in lake levels, would have relatively little effect on recreational potential. Water quality in the lake is generally good and with continued controls is expected to remain so. The area is sufficiently remote and sp sely populated so that the growth of recreational demand is not likely to outstrip the capacity of the Corps and other agencies to provide facilities in the foreseeable future. The slow pace of changes, physical separation of recreational and commercial uses, and early recognition of recreational as well as commercial needs increases the options available to the Corps and allows them to promote complementary use of the waterway.

3. Complementary Uses. In Western Lake Superior, the Corps has created a number of harbors designed to

serve both commercial and recreational traffic, in addition to purely commercial improvements and the construction of recreational harbors. These include the completed Grand Marais Harbor and the improvements in progress at Two Harbors. Large scale commercial improvements, such as breakwaters, turning basins, and dredging confer some benefits on recreational craft, if only because these harbors provide emergency shelter for small boats.

(k) Buford Reservoir (Chattahoochee River)

1. Introduction. Buford Dam, which forms Lake Sidney Lanier, is on the Chattahoochee River in north-central Georgia, about 35 miles north east of Atlanta. The dam was constructed by the Corps in 1957 as a multiple-purpose project. It is one of five dam projects on the ACF river system with authorized purposes, including navigation, flood control, hydropower, and stream flow regulation. The other four projects are the Jim Woodruff, George Andrews, and Walter George Locks and Dams and West Point Lake.

Buford Dam is designed to reduce flood stage in the Chatahoochee River as far downstream as West Point, Georgia, 150 miles below the dam; provide an increased flow for navigation in the Apalachicola River below Jim Woodruff Dam during low-flow seasons; and produce hydroelectric energy, operating as a peaking power plant. The increased flow in dry seasons also provides for an increased water supply for municipal and industrial uses in the metropolitan area of Atlanta and permits increased production of hydroelectric energy at downstream plants.

The area is generally wooded, interspersed with fields cleared for farming. The Corps owns fee title to almost all riparian land below the five-year frequency flood. At the time of construction, this was a common level of land acquisition. Presently most Corps projects require acquisition of land at a variable but much higher flood frequency level. Thus, public access is assured to all parts of the shoreline.

There are, however, many privately constructed homes or recreational facilities that border the Corps property at Buford. A significantly high number of

encroachments have been recorded on Corps lands. Violations include homes, boat docks, and levees as well as non-permanent types of encroachments such as cattle grazing. Violations are sometimes accidental, but development pressure to move as close to the shoreline as possible has been intense.

Lake Sidney Lanier is said to be the most popular Corps recreation area in the nation. The shoreline of the lake is highly developed by Corps, state and private recreation interests. Private interests are present on Corps property as concessionaires under leasing arrangements with the Corps or the "Lake Lanier Island Authority," a State agency.

Most of the people who utilize the lake are from the Atlanta metropolitan area. The typical visitor stays for only short periods, single days or weekend visits. Use is heavy throughout the year (over 500,000 visitor-days each month), peaking in June at nearly two million user-days for the month. Boating, swimming, and fishing each involve about 20% of all visitors, while sightseeing and other land-based uses involve more than half of all visitors.

There are eight marinas and five swimming beaches on the lake, as well as 52 boat ramps. There are 35 campsites, 46 picnic sites, 68 fishing areas and 41 areas designated for water skiing.

Fishing is an important recreational activity on Lake Lanier. Bass is the most popular sport fish but Shad, Brim, Catfish, and Sunfish species are also common. Recognition is made of the spawning requirements of the fish, and lake levels are controlled whenever possible to accommodate fish needs, although there are no required operations for this function.

2. Statement of the Problem. The high degree of recreation on Lake Lanier effectively places recreation at a higher level of priority than is either authorized or allowed when compared with reservoirs that have more normal levels of recreation use. There is a possibility, although its probability is low, that navigation may be constrained during water deficit periods by allocating water to recreation purposes. The following tale illustrates the priority of release considerations which have been applied to Corps projects in the Southeastern Division.

In the fall of 1977 the basin of the ACF experienced below seasonal rainfall, causing predictions of the stream level below Woodruff Dam to be placed at 6.5 to 7.0 feet unless releases were made from Buford Dam. The authorized depth of the ACF is nine feet, but the channel is often operated at an eight foot depth or lower during the fall low flow periods. Forecasted deficits of stream flow placed the critical period to be one of seven weeks duration. In order to facilitate the decision regarding Buford releases, Corps economists were requested to determine the costs to navigation, hydropower, and recreation if channel depths were reduced from eight feet to seven feet. Although recreation is not an authorized purpose at Buford, it is so considered as a result of an administative decision by the Division Engineer.

The added costs to navigation from ligh loading were calculated to be $234,000 for the seven-week period. It was considered probable that shippers would use the light loading option rather than diverting their traffic to overland routing for a short-term period.

The impact on hydropower from the drawdown of the Buford pool was calculated to be the loss of three megawatts in plant capability or $234 per day in revenue losses. This totals $11,466 for the seven-week period. However, the long-range effects might include an inability to meet contract commitments. The contract requires the Corps to purchase energy for the utility company if there is a loss in capacity.

The cost to recreation was considered negligible for the seven week off season period. However, costs for maintaining navigation over an extended drought period, which would result in a lowered water level at Buford reservoir during the summer of 1979, were calculated to be $4.3 million. This included loss of rental income from commercial marinas and club leases, plus loss of visitor recreation days which, at $1.88 per visitor day, were valued at $3.1 million. Calculations of idle investments for both commercial and private docks totaled $12.1 million.

After weighing the relative importance of costs to navigation, hydropower, and recreation interests, it was deciedd that navigation should be maintained although at reduced level of service. In effect, the short term, costs to navigation from reduced flows were found to be

higher than costs to hydropower and recreation. The analysis of the implications of a long-term, reduced flow under drought conditions suggests that hydropower and recreation would be given equal consideration with navigation in future decisions of this type and the decision would be determined largely by economic consideration. However the non-rigid case by case decision making process allows for flexibility in weighing considerations apart from purely economic concerns.

Low flows may occur anytime after the spring flood season, but they are usually most severe from September through November. It is only during above average runoff years that a nine-foot channel has been maintained during the fall. During drought years, lowered depths have caused the barge companies to resort to light loading and occasionally to cease operations.

3. Impacts of Variation in Lake Levels. Fluctuations in lake levels during past years have caused negative impacts upon both water and land based recreation. Lake levels falling below both ramps and unsightly shoreline exposure were common complaints during low flow periods. High flows sometimes caused flooding to shoreline properties.

In the past decade, recreation has gradually been accorded a high priority in reservoir operations because of intense public involvement. Presently, releases from Buford are made with due consideration for the impacts on recreation. Maintaining lake levels close to the normal elevation can be expected during the summer months for all but extreme high or low flows. The Corps maintains lake markers to signal hazardous locations. Therefore, sudden changes are potentially the most hazardous as the lake markers may not always be in the right place.

The situation at Lake Lanier illustrates the conflict experienced by Corps decision makers between the interests they are legally bound to serve and the requirements that are salient in a particular setting. Many Corps projects provide unanticipated benefits to recreation and thereby and thereby create an interest group that feels it has a legitimate claim to consideration in Corps decisions. Up to the present, physical conditions at Lake Lanier have permitted the Corps to satisfy all users, at slightly reduced levels of service under some conditions.

Should a major drought or low-flow situation occur, however, complying with the Corps mandate for commercial navigation could incur a very significant cost to recreation interests.

(1) Tygart Lake (Monongahela River)

1. Introduction. Tygart Reservoir is located in northern West Virginia, approximately 100 miles south of Pittsburgh, Pennsylvania. Tygart River is a tributary of the Monongahela River, which is navigable from Pittsburgh, Pennsylvania to Fairmont, West Virginia.

The reservoir was placed in operation in 1938 with the authorized purposes of providing flood control and low flow augmentation in the Monongahela River for navigation and other instream uses. There is a maximum flood storage capacity of 278,400 acre-feet for the period of mid-December through mid-March. Flood control capacity progressively decreases to 178,400 acre-feet from mid-March through April as water is stored for low flow augmentation. As long as natural river flows are sufficient the pool will be maintained at the maximum summer level (elevation 1 througn mid-September. If natural flows are low, the pool will be drawn down as required to insure the minimum flow. In any case the reservoir must be at the minimum pool level (elevation 1,010) by March so that maximum flood storage is available for spring runoff.

The operation of Tygart Reservoir creates significant changes in lake levels during the year. Between March and May the level can increase 157 feet for control of a major flood. During the summer the water surface elevation can change by 73 feet for flood control purposes and the fall/winter drawdown can start as early as July. This drawdown ranges from 28 feet to 48 feet and represents a drop in lake level of approximately 36 feet by the end of October during a normal year.

2. Recreational Activity. In the vicinity of Tygart Dam the Corps has provided and maintains a parking area, a public sanitary and concession building, overlook area, and limited picnic facilities. Except for this area, the development of recreational facilities in the federally owned portion of the Tygart Lake area is the

responsibility of the State of West Virginia under a long-term lease. The leased land, together with various parcels of state-owned land adjoining the lake, have become known as Tygart Lake State Park, on the right bank, and Pleasant Creek as Tygart Lake State Park, on the right bank, and Pleasant Creek Public Hunting and Fishing Area on the left bank. All of the land surrounding Tygart Lake to the maximum pool elevation of 1,190 is under government control, either through direct ownership or through the purchase of flowage easements.

In the State Park the following facilities are provided: a marina with storage and rental services and nearby launching ramps (under a concession agreement); a bathhouse and paved bathing area; a tent and trailer camping area; three picnic areas; ten rental cabins; and a lodge with twenty living units. The only recreational facilities in the Pleasant Creeks Area are a 31 unit campground and a 200 yard rifle range. Five boat clubs, operated by local organizations under concession agreements with the West Virginia Department of Natural Resources, are located along the south shoreline. The concession agreements permit only very limited construction such as tent platforms. Under the existing master plan for Tygart Lake these agreements will not be renewed as they expire.

There are also several private launching and docking facilities along the shore, which are subject to Corps regulations. All of the docks on the lake are built with flotation, which allows the docks to rise and fall with the water level.

Recreational use of Tygart Lake grew rather slowly over the period from 1965 to 1975 and seems to have leveled in recent years at about one million user-days per year. Sightseeing is by far the most popular activity, followed by picnicking, swimming and boating. A smaller number of users are engaged in fishing and camping, while waterskiing and hunting are the least conducted activities (possibly due to limited seasons). Approximately 65% of the public use occurs during the period from May through August.

Development of new recreational facilities is severely limited by the topography surrounding the lake. Tygart Valley is very mountainous and very few sites remain with slopes less than 15%. Construction on sites with slopes greater than 15% is difficult and expensive.

The rough terrain is one of the primary attractions of the area since it provides many appealing vistas and gives a sense or remoteness even near the developed facilities. These natural features are one reason why sightseeing is the major recreational use.

3. Recreation-Navigation Interactions. The conflict between recreation and navigation use of Tygart Lake is very specific. The large drawdown of the lake which is required to meet navigation objectives is a significant deterrent to most recreation uses. Typical problems associated with level changes of this magnitude include exposing unsightly mud flats and difficulties in maintaining boat ramps and swimming beaches. By the end of September all of the boat ramps providing access to Tygart Lake are out of the water. However, these conflicts have not led to severe problems for several reasons.

Tygart Lake is located on the western slopes of the Allegheny Mountains and is thus exposed to cold air masses coming from the north and west. There is only a very short season for water-contact sports. The only recreation users interested in access to the water in September and October are fishermen. If the Corps is able to maintain lake levels from May through August, most recreation users are satisfied.

The other reasons why problems have not developed relate to the users' perceptions of the facility. Tygart Lake has been operated in the same manner for over 40 years. Recreationists expect the lake level to fluctuate and have adapted to it wherever possible. The fact that everyone uses floating decks is an example of this adaptation. The concession stand at the marina can also be moved to adjust to different water levels.

4. Conclusions. In the case of Tygart Lake, the variation in lake level for navigation purposes is a familiar phenomenon that takes place every year, though with varying degrees of impact on shore activities depending on the actual amount of the drawdown. The use of floating docks ameliorates the impact on boating activity and boat-based fishing. A short summer season reduces the impact on water contact sports, such as swimming and water skiing.

Through the Corps' permit granting powers and control of shore uses, it has been possible to limit

recreational development to a level compatible with the basic navigation use of the reservoir. The remoteness of the facility and the rough surrounding terrain make it easier for the Corps to control public access and to limit development in order to preserve the quality of the natural environment. Cooperation between state and federal authorities has been another important element in the successful management of the resource to satisfy the needs of all users.

(m) Planning for the Tennessee-Tombigbee Waterway

1. Introduction. The Tennessee-Tombigbee (Tenn-Tom) Waterway project is being planned to provide a 232-mile navigation channel connecting the Tombigbee River at Demopolis, Alabama to the Tennessee River at Pickwick Lake, near the common boundary of Alabama, Mississippi, and Tennessee. Presently under construction, the waterway is planned to be completed by 1986. When complete, it wil connect the eastern inland waterway system with Mobile, Alabama and create a more direct water route to the Gulf of Mexico.

The waterway will contain a total of ten locks and dams distributed among three sections: a 148-mile River Section, a 44-mile Canal Section, and a 40-mile Divide Section. The River Section, which includes four sets of locks and dams, will essentially follow the existing Tombigbee River from Demopolis to a point just south of Amory, Mississippi. The Canal Section provides for a new channel parallel to the river, beginning from the northern end of the River Section to Bay Springs Lock and Dam includes five locks. The Divide Section, including Bay Springs Lock and Dam, consists of a deep cut connecting Bay Springs Lake via its tributary, Mackey's Creek, with Pickwick Lake on the Tennessee River via its tributary, Yellow Creek.

Five major lakes will be created by the waterway project. Gainesville, Aliceville, Columbus and Aberdeen Lakes are proposed for the River Section and Bay Springs Lake will be built along the Divide Section. These lakes will vary in width from a few hundred feet in some areas

to approximately two miles in others. In addition, five smaller lakes will be created along the Canal Section of the waterway.

Most of the River Section will have a minimum depth of nine feet, although portions of the lakes will be significantly deeper. The Canal and Divide Section will have depths of 12 feet with depths of 50 to 75 feet in portions of Bay Springs Lake. Bottom width of the channel will be about 300 feet except in the actual divide cut which will be 280 feet. Lock dimensions will be 110 by 600 feet with lifts ranging from 25 to 84 feet.

The land along the waterway is predominantly rural, with agricultural uses interspersed with forest. Only limited industrial activity exists in the area, although some garment factories, saw mills, forest product plants and quarries have been identified. Generally, the area is characterized by a low population density and a low average income level.

The major population centers closest to the waterway are Alicevile, Alabama and Columbus, Aberdeen, Amory and Fulton in Mississippi. Major population centers which are further removed from the project are Tupelo, West Point, Starkville and Corinth in Mississippi. It is expected that these towns will contribute significantly to the recreational usage of the waterway.

2. Recreation-Navigation Interactions. The Army Corps of Engineers has been authorized by Congress to study the recreational potential. As a result, significant planning for recreation and acquisition of recreational lands along the waterway have been part of the planning process from its beginning. More than 13,000 acres of land are planned for recreational acquisition and development, of which a large percentage has already been acquired. Approximately 10,000 acres are planned for initial development.

Recreation facilities to be provided include boat launching ramps, marinas, fishing docks, picnic areas, campsites and trails. State SCORPs were reviewed and expected visitation rates were developed in determining the needs for the various facilities.

No conflicts are expected to occur between recreational and navigational uses of the waterway. For the

most part, the Corps believes that the recreational facilities planning process, in addition to the anticipated user characteristics, will avoid such conflicts. The principal areas which could create potential conflict situations were land use conflicts, underway conflicts, lockage congestion, fleeting conflicts and water quality.

The Corps is confident that land use conflicts between recreational and industrial or commercial port uses will not exist. Access to extensive recreational sites will be made available along the Tenn-Tom. The 13,000 total acres to be acquired for recreational purposes wil be distributed along the entire length of the waterway in order to accommodate recreational users throughout the project area. In addition, the recreational site are being located so as to avoid conflict with existing and potential industrial/port facilities along the waterway. Such industrial/port facilities are expected to be small and to handle small volumes of commercial traffic.

Underway conflicts between recreational and commercial craft are expected to be minimal. Marinas and boat launching facilities are, for the most part, planned to be located away from the main navigation channel. This is intended to prevent conflicts of commercial craft with recreational craft entering or leaving the facilities. However, the location of marinas and boat launching facilities away from the navigation channel becomes more difficult in areas which are immediately downstream from proposed locks and dams, since the waterway becomes narrower in such areas.

Recreational lockage is expected to be small. The abundance of recreational boating access areas along the waterway is expected to attract primarily local participants with relatively short trip times. As a result, the Corps' sees little need for recreation participants to travel through locks since most of their boating and/or fishing can be performed on the lake where they launch their boats. The majority of the recreational craft are expected to be small boats, due to the generally low income level of the area. Of course, some long distance boaters are expected to pass through one or more of the locks, but these are considered to be in the minority.

No fleeting conflicts are anticipated by the Corps. Industrial and commercial port facilities are

expected to be minimal along the waterway, since most traffic will terminate either north or south of the project area. As a result, fleeting of barges will also be minimal. The oxbow lakes which wil be formed along the River Section of the waterway will therefore be utilized primarily by recreational boaters and fishermen.

Finally, in order to prevent water quality problems along the waterway, monitoring will be carried out by the Corps. Initially, no facilities for water contact recreation, such as swimming beaches, are planned because the SCORPs identify existing unused beach facilities in the area. However, the monitoring will indicate whether the waterway should be developed for water contact recreation.

3. Conclusions. The fact that detailed recreation planning for the waterway has been included in the Tenn-Tom planning process from the beginning is a significant step in avoiding potential recreation/navigation conflicts. Conflicts which the Corps has the most potential for alleviating are those related to accessibility and land use. The Corps has taken significant steps to ensure that recreational accessibility will be provided. However, it is necessary that the local governments bordering the waterway also work to ensure that the future location of industrial/port sites do not create conflict with the recreation sites, and vice versa. The Corps' permit process should help in this respect.

The Tennessee-Tombigbee Waterway planning process shows what can be done to anticipate and avoid conflicts by explicit consideration of recreational requirements in the early stages of project design. Not only can potential problems be identified and alleviated, but complementary uses can be enhanced and a more effective use of public monies can be made. Analysis of alternate recreational opportunities enables the Corps to avoid constructing facilities that are likely to be underused and imposing unnecessary requirements for environmental quality. This excellent start in the planning stage should be supplemented by continuous monitoring of recreational and commercial activity during the period of project operation and flexible project management capable of responding with regulatory solutions to potential conflicts before they develop into public issues.

(n) Review of Accident Data for Central/ South California

The United States Coast Guard provided to the study team a list of all reported accidents involving both recreational and commercial craft by county of reporting. When collated by analytic segment, this list showed that such accidents are widely dispersed over the waterways system with only a few accidents occurring on each segment. Coastal segments seem to have a higher incidence of such accidents than inland segments. In order to further investigate the possible utility of accident data as indicators of recreational/commercial conflict, a special study was undertaken of accidents reported in 1977 and 1978 on Segment 56, Central and Southern California. This segment had the highest reported number of recreational/ commercial accidents on the waterway system.

Of the thirty accidents reported to the Coast Guard over a two-year period, more than half proved to be irrelevant for this study. Five accidents did not actually occur on the commercial waterways or in areas under Corps control. In seven cases, the accident involved a collision between a Coast Guard, Harbor Patrol or Life Guard vessel (classified as "commercial craft") and a recreational vessel indistress which they were trying to help. Four other cases involved miscellaneous purposes: a company-owned cruiser, a converted former commercial boat, and two rented sailboats. These four should have been classified as recreational/recreational collisions.

The remaining fourteen accidents occurred in dispersed areas along the segment: the Los Angeles-San Pedro-Long Beach Harbor area, Newport Beach, the Redondo-Marinda Del Ray area, Santa Barbara, Oxnard and San Diego. Of the fourteen collisions, five occurred when commercial vessels struck docked or moored recreational vessels, and the rest were collisions in open water. Of the thirty total accidents, the places where vessels had the most trouble were at the mouth of the Channel Island Harbor, at San Pedro Lighthouse, and in the Newport Bay and channel. Long Beach Marina was also the site of problems as indicated by the accident reports.

In almost all cases the accident reports attributed the accidents to unsafe boating practices or poor judgment on the part of recreational boaters. In only one case was an accident attributed to congested conditions (during a weekend boat race), and in one case the narrowness of the channel was mentioned as a problem.

This review of data from the segment with the greatest number of recreational/commercial accidents indicated that little of significance could be learned from further analysis of this type of data. Recreational/commercial accidents are so infrequent and so widely dispersed, and so often prove to be defined in an irrelevant fashion that they cannot be used as reliable indicators of conflict.

SUMMARY OF CASE STUDY ANALYSES

The construction, operation and maintenance of commercial navigation facilities has both positive and negative effects on recreational use of the national waterways as described in the above case studies. These effects are summarized in Figure VI-A and discussed below by type of facility.

(a) Locks and Dams

Once completed, the construction of locks and dams provides a substantial benefit to recreational boating by regulating flow velocities and by providing safe passage over a stretch of river that might otherwise be dangerous or unavailable for recreational use. Pools created above locks and dams may offer new opportunities for swimming, water skiing, and other watercontact sports. On the other hand, locks and dams may make it difficult to engage in "river running" types of activities such as rafting, tubing or kayaking.

The impacts on fishing may be either positive or negative. Locks and dams will alter local flow characteristics, possibly disturbing existing fish habitat, but also

Figure VI-A

Summary of Recreation-Navigation Interactions At Waterway System Facilities

NAVIGATION FACILITIES	Recreation Activities: Boating	Swimming	Fishing	Shore Based
Locks and Dams				
- Construction	+	+	+ -	+ -
- Operation	+ -			+ -
- Maintenance				
Pools and Channels				
- Construction	+	+ -	+ -	+
- Operation	-	-	-	-
- Maintenance	+	-	-	+ -
Ports and Harbors				
- Construction	+	-	+ -	+ -
- Operation	+ -	-	-	-
- Maintenance	+	-	+ -	+ -
Lakes and Reservoirs				
Construction	+	+	+	+ -
- Operation	-	-	-	-
- Maintenance				

possibly creating more favorable conditions for fish development. In certain caes where fish migrate long distances to their spawning grounds, locks and dams may present a major obstacle unless mitigating measures are included in the design. Shore-based activities are relatively unaffected by lock and dam construction; some might see on as an unsightly intrusion in an otherwise unspoiled riverine environment, but most recreationinsts find locks and dams to be interesting focal points for shore-based activities such as picnicking, hiking and sightseeing.

The operation of locks and dams also benefits recreational boaters as long as they have free access to the facilities. Conflicts arise when there is congestion between recreational and commercial traffic, resulting in delay. Demand for recreational use of locks is higly seasonal and peaks on weekends and holidays. Commercial traffic is more regular but also exhibits seasonal peaks. The most serious delays seem to be experienced where the volume of commercial traffic is high, resulting in very large tows that sometimes have to be moved through locks in two sections.

The perception of conflict associated with delay is partly a function of the value placed on time by the waterway user. In general, the weekend boater places a high value on time spend in this form of recreation, compared to the value of time to the commercial shipper who has chosen the waterway mode of transport. Consequently, delays to recreatinal boat traffic result in high perceived costs which are then translated into political pressures on lockmasters to accord priority to recreational craft.

A number of technological and institutional solutions to this problem have been tried in a variety of settings, as discussed in the case studies. Construction of larger locks on the Ohio has permitted the use of smaller locks for small tows and recreational craft. Special lockage times for recreational craft, posted in advance, seem to work well on the Columbia. A variety of technological alternatives have been studied for the Upper Mississippi, including queueing facilities, floating locks, mobile boat carrier, rail and inclined lifts. However, most of these

solutions appear excessively costly in comparison to scheduling options combined with public information programs.

It has been observed that recreational/commercial conflicts at locks and dams seem to peak shortly after delay times come to exceed the tolerance of the average recreational boater. Public pressure to do something about the problem eventually results in the development of scheduling policies, combined with a growing public awareness of the variety of competing interests involved and the rights of others to use the waterway system. Commercial interests have generally been quite cooperative with scheduling decisions designed to reduce peak loads and make more effective use of existing facilities. While a negotiated solution may not permanently solve the problem of growing demand for lock space, it can buy time for the study of technological improvements and for the gradual redistribution of demand to less heavily used facilities.

The operation of locks and dams has relatively little impact on swimming, fishing, and shore-based activities at the pools above and below them. Naturally, fishing and swimming cannot be carried out too near to the lock machinery. However the variation in pool levels resulting from lock and dam operation for navigation purposes is insignificant for recreational activity.

Heavy lock traffic and lengthy delays could result in an accumulation of waiting vessels just above the lock, consuming surface space that might otherwise be available for recreational activity. Such delays might also produce localized air quality and water quality impacts during peak periods. These impacts could adversely affect recreational potential for shore-based or water-based activities in the immediate vicinity of the lock. However, no such conflicts have been identified in the case studies.

There has been no example to show that lock and dam maintenance in any way affects recreational potential, except to insure continuous operation, thereby providing a benefit to recreational boaters. Pools behind shallow dams might conceivably silt up enough to require channel dredging. However, this activity would have a very minor

impact on those recreational uses which would be permitted in the vicinity of the lock and dam structures.

(b) Pools and Channels

The channelization of rivers and the creation of pools through lock and dam facilities also provides benefits to recreational boaters through increased safety, navigability, and public access. Impacts on swimming and fishing may be positive or negative, depending on the characteristics of the river in its natural state and the channel design characteristics. Public access to wharfs, bridges, banks and levees provides a benefit to fishermen, particularly in more urban areas where such access is relatively scarce. On the other hand, river training and commercial traffic may have a negative effect on the size and variety of the fish population.

The potential for swimming and other water-based sports depends on flow velocities, water quality and shore access as well as on the existence of protected areas closed to boating traffic; thus, channel configuration could be an important variable. Shore-based recreational uses are enhanced by public access and land use controls, as well as shore-based recreational facilities such as picnic grounds, campsites, and hiking or bike trails. On the other hand, channelization may reduce some of the visual interst and/or vegetation provided by a more meandering or rapid river in its natural state. This potential impact can be avoided by paying attention to landscape criteria in the design stage.

The principal conflicts that arise out of channel operation for recreational and commercial use are those that derive from congestion. These conflicts seem to occur in particularly narrow channels and at areas where there is particularly heavy use, as indicated by large numbers of marinas and launching facilities. Congestion seems to be the principal factor involved in accidents between recreational and commercial craft, although such accidents are relatively few in number compared to accidents involving two or more recreational craft.

The second major factor in channel operation is the effect of sudden local variations in water level. This may be due to a "surge" or latitudinal wave created by water releases upstream, or to a "wash" or longitudinal wave created by passing vessels. The former case might be due to lock operations, although their effect is usually insignificant; it is much more likely to be due to storm runoff or to hydropower releases, both of which are unrelated to commercial navigation.

In the latter case, the wave may be created by recreational, commercial or other types of craft. Its impact is a function of boat size, shape and speed, channel configuration, and streambank soils. In the absence of bank protection, these waves can be a major problem in causing bank erosion.

Moored boats, marinas and launching ramps may suffer significant damage from such waves. Waves also create a hazard for small boats in operation and present difficulties for recreational fishing. Beaches and gently sloping areas suitable for recreational swimming are likely to be particularly susceptible to erosion. The surrounding land area, required for shore-based recreational uses, may also be lost, made unsafe or unsightly by bank erosion.

Damage to boats and shore property which is clearly attributable to commercial navigation activity provides sufficient grounds for lawsuits against commercial shippers. Recognizing this fact, shippers in heavily trafficked area comply with, and sometimes even voluntarily impose, speed limits in order to minimize the effects of their wash or wake. The effect of these speed limits is to increase transport time and therefore the cost of commercial shipping. Speed limits may also be imposed on areas where wash problems are created primarily by recreational craft, and commercial shippers are generally required to observe speed limits as well.

Finally, channel maintenance often requires dredging an disposal of dredged material. Dredging presents only a minor safety hazard to recreational boaters and provides significant benefits to larger recreational craft. However, it may have negative effects on water quality that

adversely affects swimming and other water-contact sports. Generally, dredging also disturbs the underwater habitat and has a negative effect on fishing, although in the Gulf of Texas it has been reported to have a positive effect through bringing shellfish and bottom fish to the surface.

Disposal of dredged material on the inland waterways presents a major problem to the Corps. The options depend upon the composition and quality of the materials and the extent to which they contain noxious or hazardous wastes. Clean sand and silt can be used for beach creation, thereby generating benefits to swimming and shore-based uses. Dredged material can also be used to create islands which can become significant ecological niches for birds, fish and wildlife. Stable soils can be used as fill for swampy areas; the result can be positive or negative for recreation, depending on the use later mae of the site. Contaminated dredged materials will create a hazard no matter where they are located, and careless or unplanned dumping on disposal sites near the waterways could have a negative effect on both water-based recreation and shore-based land uses.

(c) Ports and Harbors

Port construction by the Corps that includes recreational facilities provides a clear benefit to recreational boaters. Generally, ports and harbors have high levels of commercial traffic and are therefore unsuitable for swimming and other water contact sports. Harbors offer both positive and negative consequences for recreational fishing; public access is provided (and often heavily used), but water pollution and constant boat activity make them an inhospitable habitat for fish. Ports and harbors also provide essential support services for marine recreational fishing.

The impacts of ports and harbors on shore-based land uses are complex. Port activities consume land and shoreline space that might otherwise be available for recreational use. The growth of commercial ports is closely correlated with the growth of urban and industrial activities in the immediate area. These activities also consume land and water resources in competition with the growth of

urban and industrial activities in the immediate area. These activities also consume land and water resources in competition with recreational uses. They also generate population growth and income and thereby increase the demand for recreational facilities. However, many shore-based users find ports and harbors to be significant points of interest for sightseeing and aesthetic enjoyment.

The operation of ports and harbors may bring commercial vessels into conflict with recreational craft if a congested or limited access situation exists. Congestion is created by high traffic volumes in relation to channel capacity and is exacerbated by physical constraints on the movement of smaller craft. Congestion seems to peak at the point where commercial traffic volumes just exceed the average recreational boater's tolerance for danger, delay, noise, and air and water pollution. Past this point, recreational use of commercial areas seems to fall off, except when boaters are forced to pass commercial facilities in order to get from their access point (marina, park or launching ramp) to the area where they can enjoy a recreational boating experience.

Harbor operations and channel maintenance provide valuable support to commercial sport fishing, which can be seen as either a recreational or a commercial use of the facility. In other respects, channel maintenance in harbors generally creates a negative impact on the environment, although it often benefits recreational boaters. Harbor bottom sediments are likely to contain more toxic wastes than stream sediments, and flushing actions are retarded by tidal flows.

Many ports and harbors are located at river mouths where there is a delicate and ecologically endangered estuarine environment. This makes dredging and dredged material disposal more difficult and creates a potential for negative impacts on recreational uses in this environment. However channel maintenance along the coast can provide clean sand for beach creation and replenishment, thereby generating a major positive impact for swimming and shore-based recreation. Offshore islands can be created using dredged material, and there is always the possibility of ocean dumping if a desirable site for dredged material disposal cannot be obtained.

(d) Reservoirs

There is no direct interaction between commercial navigation and reservoir recreation because reservoirs are by definition close to commercial traffic. The Corps operates a large number of reservoirs around the country which provide extensive opportunities for water-based recreation. Only a few of these reservoirs are linked to the commercial waterways system through the fact that water releases from these reservoirs are authorized for low flow augmentation in a downstream channel which is maintained for commercial navigation purposes.

The construction of reservoirs, for these or other purposes, generally has a positive impact on recreational boating, swimming, and fishing potential in the area. It eliminates a certain amount of land from potential land uses, such as hiking, camping or hunting, but it provides public access to a water resource and thereby encourages the growth of water-enhanced activities in the surrounding area. Much can be done in the planning and implementation of land use controls to maximize recreational benefits to shore users.

The actual operation of the reservoir related to commercial navigation, i.e., the release of water for low flow augmentation downstream, can cause significant variations in lake levels, which in turn can have major effects on reservoir recreation. The extent of the impact partly depends on whether the change has been foreseen and facilities designed to accommodate it. A drop in the lake level of ten feet can be critical for fixed facilities such as marinas and beaches, while a variation of thirty to fifty feet can be absorbed by properly planned facilities.

The potential negative impact on recreational boating is the elimination of boat access due to a drop in lake level well below the base of a marina or launching ramp. Surface water space is also slightly reduced by the variation in lake level, but this impact is insignificant in comparision to the effects of loss of shoreline access.

Swimming is also negatively affected when water levels drop below the level of public or private beaches. The exposed banks are likely to be muddy rather than sandy, and underwater vegetation may also be exposed. For the same reasons, bank fishing loses its attractiveness. The remaining water may be too shallow to permit the enjoyment of swimming or fishing, and some fish habitats could be endangered. The unsightly and even noxious aspects of the exposed lake bed also act as a deterrent for shore-based land uses.

It should be noted, however, that negative impacts on reservoir recreation due to water releases may be offset by recreational benefits downstream. The maintenance of minimum channel depth benefits recreational boaters as well as commercial shippers. Keeping stream levels up to normal permits the continuation of downstream swimming and fishing activities and prevents negative effects on streamside land uses. Therefore, the decision to augment low flows through reservoir releases must take into account the balance of recreation impacts across the whole river system.

The case studies indicate that, as a practical matter, reservoir releases are decided through an interactive process that balances the needs of all the interests actively involved and participating in this process. Commercial shippers accord legitimacy to recreation interests and are willing to abide by a compromise in the best interests of both parties. As with locks and dams, it appears that reservoir conflicts can be largely controlled through institutional flexibility and public participation.

FORECAST FUTURE RECREATION DEMAND

Future levels of demand for recreational use of the waterways will be an important element in determining future recreation-navigation interactions along with the future level of commercial navigation activity which has been developed in Element B - Traffic Forecasts.

Information on present recreational use levels, conflicts and complementary uses was used to identify the

segments and facilities in the waterway system which are likely to be the locale of future recreation-navigation interactions. Recreational demand forecasting was then confined to those segments and facilities determined to be significant for this study.

(a) Selection of Significant Segments

A three step procedure was used to identify segments with potential conflicts. The first group of segments included are those having high navigation use and high recreation use, as indicated by data provided in the NWS Inventory and/or or the RRMS. They include:

- 2 - Lower Upper Mississippi River.
- 9 - Illinois Waterway.
- 11 - Upper Ohio River.
- 12 - Middle Ohio River.
- 16 - Monongahela River.
- 42 - New Jersey/New York Coast.
- 46 - Lake Erie.
- 47 - Lake Huron.
- 48 - Lake Michigan.
- 49 - Lake Superior.
- 50 - Puget Sound.

Three other segments have probable unreported high levels of recreation use, and were included:

- 41 - Chesapeake and Delaware Bays.
- 55 - San Francisco Bay.
- 56 - Central and Southern California Coast.

Additional segments were included on the basis of identified conflicts. Segments included in this category are as follows:

- 1 - Upper Missouri River.
- 13 - Lower Ohio River III.
- 24 - Arkansas and Verdigris.
- 51 - Upper Columbia River.
- 52 - Lower Columbia River.

Other segments were identified as having high recreation use but only medium to low levels of commercial navigation, with no conflicts at the present time. Eleven more segments were added on this basis:

- 10 - Missouri River.
- 21 - Cumberland River.
- 22 - Upper Tennessee River.
- 23 - Lower Tennessee River.
- 25 - Ouachita, Black and Red Rivers.
- 33 - Florida Gulf Coast.
- 35 - Black Warrior River.
- 36 - Alabama-Coosa Rivers.
- 38 - Apalachicola, Chattahoochee and Flint Rivers.
- 44 - Upper Atlantic Coast.
- 53 - Oregon/Washington Coast.

Two more segments with only medium to low levels of both recreational activity and commercial navigation at

the present time, but with specific high-use facilities were also included. These segments and facilities are:

1. 17 - Allegheny River (Lock #2).

2. 43 - New York State Waterways (Lock #23 on the Erie Canal).

This set of 32 significant segments provides complete coverage of nine reporting regions (Upper Mississippi, Illinois River, Tennessee River, Arkansas River, Tombigbee-Alabama Coosa-Black Warrior, Middle Atlantic Coast, North Atlantic Coast, Washington/Oregon Coast, and Columbia-Snake Waterway/Willamette River). It provides partial coverage of six regions (Lower Upper Mississippi, Ohio River, Baton Rouge to Gulf, Gulf Coast East, Great Lakes and California Coast.

Recreation demand forecasting was carried out for four specific types of facilities (pools, locks and dams, reservoirs, find ports and harbors and for four specific recreational activities (swimming boating, fishing and other) on each segment. The following paragraphs describe the findings by type of facility. Recreational demand forecasts are summarized by segment and reporting region at the end of this section.

(b) Recreation Demand in Navigation Pools

Recreation use forecasting was performed for 140 navigation pools destributed among 22 waterway segments. Table VI-3 lists the waterway segments and the number of navigation pools on each for which recreation use was forecasted. With the exception of one segment, the Missouri River, the navigation pools on these waterways were created immediately upstream from each of the one or more lock and dam facilities which exist. The Missouri River, on the other hand, is a channelized, free-flowing waterway with no lock and dam facilities or navigation pools. For purposes of forecasting recreation use on this waterway, however, the entire channel is treated as if it were one large pool.

Ship channels with high recreation use were generally not included in the pool forecasting procedure. This includes the following high use facilities. Okeechobee Waterway, Cape Cod Canal, Duth Ship Canal and Harbor Park, and Lake Washington Ship Canal. The first two facilities have high recreational boating use as well as fishing, sightseeing, and other land-based activities. However, they have relatively low levels of commercial navigation use and these levels are not expected to increase in the future. Recreational use of the latter two facilities is almost exclusively sightseeing and other land-based activities. Thus, no future conflicts between commercial navigation and recreational use are foreseen for these facilities.

In general, the forecasts of use for the four recreational activities appear to be rather conservative, although they are considered to be in a reasonable range. Any underestimation of actual growth which exists in the four sets of forecasts is probably due to the fact that growth was only related to population change (see appendix B for details of recreation forecasting methodology).

The accuracy of the 1977 estimates and the future year forecasts for the various navigation pools varies by pool and data availability. Assuming that the RRMS data concerning total user-days and activity mix are accurate, those pools for which the base data were available rather than estimated by the model are likely to have the most accurate forecasts.

1. Swimming. Although the number of swimming user-days is generally lower than those for other recreation activities, the user-days growth rates between 1977 and 2000 are higher on the average for swimming. This growth may be slightly overstated if swimming pool development continues to increase in the future, or if waterway pollution levels do not decline as predicted.

Approximately two-thirds of the pools will experience increases in swimming user-days between 1977 and 2000, due to increases in population within 50 miles of each pool during the same period. About 25% of the pools experience population declines. Other pools are shown to have no swimming use in 1977 according to the RRMS data, and are forecasted to continue having no swimming use

Table VI-3

Segments Selected for Recreation Use Forecasting Analysis on Navigation Pools

Segment Number	Segment	Number of Pools[1]
1	Upper Mississippi River	25
2	Lower Upper Mississippi River	3
9	Illinois Waterway	12
10	Missouri River[2]	1
11	Upper Ohio River	10
12	Middle Ohio River	5
13	Lower Ohio River-III	3
16	Monongahela River	9
17	Allegheny River (Lock No. 2)[3]	1
19	Kentucky River (Lock No. 1)	1
21	Cumberland River	7
22	Upper Tennessee River	8
23	Lower Tennessee River	3
24	Arkansas-Verdigris Rivers	19
25	Oauchita - Black and Red Rivers	5
35	Black Warrior River	7
36	Tombigbee and Alabama-Coosa River	4
38	Apalachicola, Chattahoochee and Flint Rivers	5
41	Chesapeake and Delaware Bays (A & C Canal)	1
43	New York State Waterways (Erie Canal-Lock 23)	1
51	Upper Columbia-Snake Waterway	8
52	Lower Columbia-Snake Waterway	2
		140

NOTE: [1]The number of pools reflects only those pools for which recreation use is being forecasted.

[2]Although the Missouri River does not contain any locks and dams or pools, the entire channel is treated as if it were one large pool.

[3]Kentucky River Lock No. 1 was included because NWS Inventory data indicated that it was a high-use facility. However, further investigation revealed that the inventory data are incorrect in this case. Therefore, the Kentucky River has been treated as a low-use segment in this report.

through 2000. It is assumed that characteristics unique to those pools presently prohibit or discourage swimming and that those same characteristics will continue throughout the rest of the century.

The pools shown to have the highest rates of increase (around 50%) in swimming use between 1977 and 2000 are the Upper St. Anthony Falls on the Upper Mississippi, the Brandon Road Lock and Dam and the Lockport Lock and Dam on the Illinois Waterway, the Cheatham Lock and Dam on the Cumberland River, and the Apalachicola River below Woodrufff Lock and Dam. Many of the other pools have swimming growth rates during the period which exceed 20%.

Many of the pools experiencing declines in swimming use also have high rates of change. Some of the largest percentage declines occur at the Claiborne Lock and Dam and below the Claiborne Lock and Dam on the Alabama-Coosa segment, the Demopolis Lock anid Dam on the Black Warrior/Tombigbee segment, the Dalles Lock and Dam on the Upper Columbia and below the Norrel Lock and Dam on the Arkansas-Verdigris segment.

In terms of absolute numbers of swimming user-days, the areas experiencing the greatest amount of use are Pool #26 on the Lower Upper Mississippi, the Wolf Creek, Old Hickory and Barkley Pools on the Cumberland River, and the Dardanell Pool on the Arkansas River.

2. Boating and Waterskiing. Ideally, the boating and waterskiing category should have been disaggregated into several different categories, such as small-craft boating, large-craft boating and waterskiing. This was not done since no base year data were available for boating use by type or size of craft. More than likely, disaggregation into several categories would have caused the income variable to be more important to the equation since income certainly influences the type of boating which occurs. However, all boating and waterskiing aggregated into a single category diminishes the effect of income.

Like swimming, approximately two-thirds of the pools experience an increase in boating and waterskiing activity between 1977 and 2000. With the exception of one pool, Brandon Road on the Illinois Water, all increases are less than 10% throughout the period. Brandon Road

pool is estimated to increase by almost 15%. Other pools with high forecasted growth include Dresden Island on the Illinois Waterway and Wheeler Lock and Dam on the Upper Tennessee River.

Almost all of the remaining one-third of the pool experience decreased in boating and waterskiing activity, due entirely to decreases in population. The pools experiencing the greatest declines in use are Andrews Lock and Dam on the ACF River System and the Claiborne Lock and Dam on the Alabama-Coosa. All other declines are less than 10% in magnitude.

Several pools experience greater than one million boating user-days per year throughout the period. These pools are Lock and Dam #26 on the Lower Mississippi, the Wolf Creek Dam and Old Hickory Lock and Dam on the Cumberland River, and Millers Ferry Lock and Dam on the Alabama-Coosa. In fact, the latter pool exceeds two million boating user-days. Additionally, the entire Missouri River exceeds one million user-days per year.

3. <u>Fishing</u>. It is impossible to determine from the fishing user-days base data and forecast values what percentage is attributed to shore-based fishing in relation to boat fishing. As a result, the ability to identify the exact conflicts which would potentially occur between commercial navigation use and fishing is reduced.

More than 70% of navigation pools experience an increase in fishing user-days during the 1977-2000 period. Most of the growth rates do not exceed 10% during this period, although certain pools do exhibit larger increases. By far the greatest increase occurs at Lock and Dam #1 on the Upper Mississippi segment where fishing more than quadruples in the 23-year period. Other pools which have relatively high growth rates are Lock and Dam #2 on the Upper Mississippi, the Chouteau, Newt Graham and Perry Locks and Dams on the Arkansas-Verdigris, and the portion of the Lower Tennessee segment which is below the Kentucky Lock and Dam.

For those pools experiencing losses in fishing use, the rates of decline are also generally less than 10%. Pools which decline at higher rates include the Demopolis Lock and Dam on the Black-Warrior-Tombigbee segment, the Claiborne Lock and Dam on the Alabama-Coosa and

the portion of the Arkansas-Verdigris segment below the Norrell Lock and Dam.

Ten pools have high existing levels of fishing use, two of which exceed two million user-days and the remainder exceeding one million. Those pools exceeding two million user-days of fishing are the Millers Ferry Lock and Dam on the Alabama-Coosa and the Walter F. George Lock and Dam on the ACF Rivers System. The pools exceeding one million-user-days of fishing per year are Lock and Dam #26 on the Lower Upper Mississippi, the entire Missouri River, the Wolf Creed Dam and Old Hickory Cheatham and Barkley Locks and Dams on the Cumberland River, the Dardanelle Lock and Dam on the Arkansas-Verdigris Rivers and the Jim Woodruff Lock and Dam on the ACF Rivers System.

4. Other Recreation. This section includes a variety of hand-based activities which require no special equipment. In 1977, a total of 27 navigation pool projects experienced greater than one million user-days of "other" recreation. Of this total, one pool exceeded four million, two pools exceeded three million, seven exceeded two million and the remainder exceeded one million. The pools having the highest use are Barkley Lock and Dam and Wolf Creek Dam on the Cumberland River and McNary Pool on the Upper Columbia. In addition to these pools, the entire Missouri River's "other" recreation user-days exceeded 10 million.

Slightly less than two-thirds of the navigation pools experience at least small positive growth rates between 1977 and 2000. Although the majority of these increases is less than 10% in magnitude, several pools do experience higher growth rates. These include the Upper St. Anthony Falls Lock and Dam on the Upper Mississippi segment, Lock and Dam #26 on the Lower Mississippi segment, the Lockport, Brandon Road and Dresden Island Locks and Dams on the Illinois Waterway, the Cheatham Lock and Dam on the Cumberland River, the Wheeler Lock and Dam on the Upper Tennessee segment, and the Murray and Terry Locks and Dams on the Arkansas-Verdigris.

Most of the rates of decline in "other" recreation user-days are also rather small, although several pools have significantly larger drops. They are the area below LaGrange Lock and Dam on the Arkansas-Verdigris, the Claiborne Lock and Dam on the Alabama-Coosa, and the Lower Monumental on the Upper Columbia segment.

(c) Recreational Craft Demand at Locks and Dams

Lock and Dam operation primarily affects recreational boating activity. The relevant variable is the number of recreational craft demanding use of lock facilities. A regression approach similar to that used for the navigation pools analysis was applied to the forecasts of recreational craft through locks. Forecasts were made for each of the Locks and Dams corresponding to the navigation pools for which forecasts were made in the previous analysis.

Three high-use lock facilities were not included in the recreational craft analysis. These include the Calcasieu Salt Water Barrier on the GIWW West (Middle) segment, the Chittenden Salt Water Barrier on Puget Sound, and the W.G. Stone Salt Water Barrier provides adccess to the commercial waterway system for recreational craft on the Calcasieu River, but it carries on commercial traffic. The Chittenden Salt Water Barrier has a double chamber and handles recreational craft separately from commercial traffic. Levels of both commercial and recreational traffic through the Stone Salt Water Barrier are relatively low. No future recreation/navigation conflicts are anticipated at any of these facilities.

Basically, the forecasted changes in the number of recreational craft passing through locks are quite minor during the 1977-2000 period. In fact, in many cases the change is so minor thse Locks and Dams can be considered to experience virtually no change. The increase or decrease in number of recreational craft does not exceed five percent for any Lock and Dam facility by the year 2000.

Although the majority of the Locks and Dams tend to hve fewer than 5000 recreational craft locking through, many of the facilities do have existing high volumes of recreational boating traffic. These volumes remain high throughout the period. Four facilities have greater than 10,000 recreational craft locking through each year: Locks and Dams #3, #7, and #14 on the Upper Mississippi segment and the O'Brien Lock on the Illinois Waterway.

The number of recreational craft passing through each lock is non-linearly related to the amount of boating use in the associated pool. As the amount of boating use in the pool increases, the number of recreational craft lockages increases at a high rate until a certain point when it begins to level off. This relationship is due to the fact that a greater percentage of long-distance boating enthusiasts exist when there is a low total boating use level in the pool. As the total level increases beyond a certain point, these long-distance boaters comprise a smaller percentage and therefore, the lockage rate levels off.

Because of the nature of the relationship, very little change in future recreational craft lockages is anticipated. However, due to the generally low r^2 value of the predictive equation (see Appendix B) it is assumed that other factors are important in determining recreational craft lockages. The very slow growth forecast in this study is consistent with the slow growth forecasted for larger motorized recreation craft and the effects of increasing congestion at locks. However, the inclusion of more variables in the regression equation could possibly result in higher growth rates.

(d) Recreation Demand at Reservoirs with Navigation Releases

Recreation demand was forecast on the four reservoirs with navigation releases, (Oolagah, Tygart, Buford and Gavins Point), due to the potential impacts of navigation releases from these reservoirs on water levels and recreational use. These four reservoirs represent a spectrum of geographical areas, diversity in associated recreational activity and a variety of socioeconomic characteristics in their immediate areas. Thus, separate forecasts were made for each individual reservoir as well as for each type of recreational activity. The forecasting methodology was similar to that used in the pool analysis in that population, income area available, and distance from the facility were treated as the major determinants of future recreation demand.

In the case of all four reservoirs, recreation demand for each activity is forecast to increase, while percentage by activity type is expected to remain constant. Historically, these trends are not reflected in RRMS user-days visitation data nor in rates for activity participation, at certain reservoirs. In addition, the rates of increase experienced by the reservoirs in past years and the projected rates of increase often do not coincide. These differences can be attributed to a number of factors and conditions unique to each reservoir or the region in which each reservoir is situated.

1. <u>Tygart Lake</u>. Tygart Lake, situated in a low income rural area of mountainous West Virginia, is a moderately attended reservoir which hosts a high percentage of sightseeing and other water-enhanced activities. Recreation demand by activity is projected to increase roughly 16% every five years to the year 2000. These rates of growth are similar to those experienced by most activities from 1972 to 1977, with the exception of fishing. During this period, fishing experienced a 65% increase. Fishing use has increased on the Tygart due to water quality improvement, fishery improvements and drainage corrections during the last five years.

Water related recreation activities are prominent in the summer months, while fishing is most popular from February to May and in October. Other activities take place primarily between April and September.

Factors particular to the Tygart which impact recreation include climate, hydrology and topography of the area in association with reservoir operations. These operations reduce recreation activity from October through February to a negligible level. Storage depletion for low flow augmentation does not impact recreation during the summer, as pool elevations are maintained past mid-July. A drop of 10 feet by the end of August only moderately reduces surface area and has little impact. However, in a dry year, as water releases accelerate drawdown, recreation is affected, commencing early in September. By the end of October, even in wet years, a thirty foot reduction in lake level reduces use of the lake to near zero. Other factors such as cold weather, ice and more difficult winter access, serve to curtail use almost entirely during the winter.

2. Gavins Point (Lewis and Clark Lake). Gavins Point located between the eastern South Dakota-Nebraska border, is a heavily used recreation facility despite its rural location. Gavins Point is used fairly evenly with regard to activity types. In general, visitors tend to engage in only one specific activity per visit.

Projections indicate that demand will increase 11 to 15% over each five-year period from 1985 to 2000 for each activity type. From 1972 to 1977, however, Gavins Point vastly exceeded this growth rate. During this period, boating increased 32%, fishing and other uses 45%, and swimming 108%. However, in 1978 the total number of user-days, and therefore the associated activity participation, had declined almost to 1976 levels.

Seasonal use at Gavins Point follows a fairly constant pattern. Peak visitation and use run from Memorial Day to Labor Day, during which time campground fees are charged. Gavins Point's high visitation growth rate is not attributable to usual visitation patterns. The reservoir attracts visitors from much greater distances than the Oolagah, Buford and Tygart Reservoirs. This is the result of fewer recreation alternatives existing in areas near Gavins Point, especially in northern Nebraska and western Iowa. Weekend excursions from Omaha, over 100 miles away, are not uncommon.

Corps policices regarding facility use will also impact visitation in the future. Before the 1979 season, unlimited campground use was allowed. Severe crowding at some facilities required modifications to this policy. Additional campers are directed to overflow campgrounds where electrical hookups and other conveniences are not available. This policy, implemented mostly on weekends and high-use periods, indicates high use and congestion at certain types of facilities. The policy will have the effect of decreasing the rate of growth of visitation.

In 1978, Gavins Point experienced significantly lower visitation, not totally attributable to new counting methods or Corps policies. Preliminary indications based on first half of the year figures, indicate even lower visitation in 1979. The trend of high visitation growth rates may be changing. Both trends are associated with higher gasoline prices, which discourage long distance driving and encourage lengthier visits.

3. <u>Oolagah Reservoir</u>. The Oolagah Reservoir, which supplies water to the Arkansas River, is located about 20 miles north of Tulsa, Oklahoma. The reservoir receives high to moderate recreation use and hosts a very high percentage of fishing use. In addition, shore-based water uses prevail, while water contact activities such as boating and swimming are less important.

Projected demand in the region of the Oolagah is expected to increase approximately 19% for each five year period to 2000, for each activity type (see Table VI-4). However, activity participation for the five years from 1972 to 1977 differs significantly from this rate and differs even more significantly from activity to activity. Boating participation declined 43% during this five year period, while swimming declined 51%. Fishing and "other" activities are evenly distributed over the year, according to monthly visitation data.

The factors that affect use of Oolagah and which explain its unusual activity participation growth rates are the manner in which the Oolagah and other nearby reservoirs are managed and operated by the Corps. Most of the recreation visitation and demand at Oolagah comes from the Tulsa metropolitan area. However, Tulsa is served by two reservoirs, Keystone and Oolagah. The physical nature of these lakes is markedly different. At Keystone, the shoreline is built up with various private boat docks, residences and other facilities. Keystone has developed so as to cater to certain types of activity, most notably boating, water skiing, swimming and activities that require less scenic surroundings.

At Oolagah, where the Corps does not allow private boat ramps and shoreline development, the shoreline is uncluttered, more scenic and draws a different type of visitor. The facilities at Oolagah reflect this conscious planning effort. While Keystone has numerous launching facilities and electrical hookups, Oolagah does not. In addition, access to the two reservoirs favors Keystone, which is half the distance from Tulsa. Keystone is also served by a major turnpike, while roads to Oolagah are older, narrower and rougher.

These facors explain the Oolagah's low boating and swimming participation and the decline experienced by these activities during the 1970s. Corps policies and

location of the resevoirs serve courage fishing and other water-enhanced activities.

In addition to policies implemented by the Corps, lake levels impact visitation. To a great extent, Oolagah's shoreline lies on flat flood plain where a fall or rise in water level will significantly affect facility use. For almost every year in the 1970s, water level has been such to deter use. In 1973, 1974, and 1975, floods filled the lake with debris and caused certain public use areas to close in the spring and summer. In 1976, floods occurred on two of three major visitation weekends, and an estimated 100,000-250,000 visitors did not use Oolagah. In 1977, drought drew lake levels below normal, exposing stumps, which discouraged certain types of recreation activity. However, during this time other formis of water-enhanced recreation were not considered to have been affected despite Oolagah's large expanses of shallow water. It is estimated that a draw down of nearly twice the record low level would be necessary to significantly deter those forms of recreation.

4. Buford (Lake Sidney Lanier). Buford reservoir, or Lake Sidney Lanier, is the most heavily attended Corps project in the nation, a fact attributable to a great degree to its tan area. The reservoir, which feeds into the Apalachicola-Chattahoochee-Flint waterway system, is used heavily for all types of recreation activity,with relatively high boating and swimming participation.

Demand at Buford is projected to increase rather dramatically, between 21 and 31% for all activities, every five years to the year 2000. Actual use at Buford has declined from between seven and 20% for the various activity types over the five year period from 1972 to 1977. Boating, swimming and fishing experienced the largest declines.

The factors that have influenced visitation and activity participation at Buford are related to Buford's intense use. Boating on weekends is considered to be near its saturation point, and conflicts between fishing/powerboat use and sailboat/powerboat use are common. In addition, the proximity of other Corps projects affect Buford's visitation. Altoona and, to a lesser extent, West Point draw visitation away from more crowded Buford. Similarly, the closing of facilities for rehabilitation in

1977 decreased visitation and corresponding activity participation.

Despite the already high use at Buford, the downward visitation trend was reversed dramatically in 1978 with a 23% increase from 1977. This one year increase corresponds to a 25% average increase demand projected over five years. It is expected that the number of total user days in 1979, when compiled, will be higher than in 1978.

(c) Recreational Craft Demand at Ports and Harbors

Recreation demand forecasting for ports and harbors was attempted for 12 waterway segments. These segments are all situated either on the Atlantic Coast, Pacific Coast, the Gulf of Mexico or the Great Lakes. Particular sorts and harbors included in each segment were selected for analysis based on existing information concerning recreational and commercial use. Any port and harbor identified by the NWS Inventory as having at least 100 recreational boating ships and/or 1,000,000 commercial tons of traffic was considered to be eligible. From this list, the following ports and harbors were selected:

Harbors	Ports
Segment 33 - Florida Gulf Coast	Port of Tampa
Segment 41 - Chesapeake and Delaware Bays	Port of Washington, D.C. Port of Baltimore
Segment 42 - New York/New Jersey Coast	Port of New York
Segment 44 - Upper Atlantic	Boston Harbor
Segment 46 - Lake Erie	Erie Harbor
Segment 47 - Lake Huron	St. Clair Harbor
Segment 50 - Puget Sound	Port of Seattle
Segment 53 - Oregon/Washington Coast	Portland Harbor
Segment 55 San Francisco Bay	Oakland Harbor Port of Sacramento
Segment 46 - Central/South California	San Diego Harbor

Data was collected on marina use and projected marina expansion in these ports from the NWS inventory and telephone interviewing with port authorities, Coast Guard or Harbor Patrol.

1. Port of Tampa. It was estimated that 10 marinas and 50 launching facilities exist in the port area.

Conflicts within the port are reportedly nonexistent. The port is congestion-free and no major accidents have occurred. However, the United States Army Corps of Engineers is presently conducting a dredging project to deepen the channel, intended to alleviate a minor problem situation for boaters. Plans for the construction of a marina at South Davis Island are presently at the public hearing stage.

Since more definitive and accurate data would not be obtained through the telephone survey, it was decided to use the NWS Inventory data to derive recreational boating use. The forecasted growth in moorage demand in the Port of Tampa is phenomenal, increasing from 900 vessels in 1976 to over 13,000 vessels in 2000. This growth is primarily due to the high growth of recreational vessels throughout the State of Florida in recent years. This is undoubtedly a case in which all of the demand cannot possibly be accommodated immediately within the harbor area, resulting in an overflow of demand into adjacent areas.

2. Port of Washington, D.C. The primary data source concerning recreational boating in the Port of Washington, D.C. was the Metropolitan Police Department, Harbor Patrol Unit. The Port district is defined by the Harbor Patrol unit as the Potomac River between Woodrow Wilson Bridge on the south and the Chain Bridge on the north. Within this area are 16 marinas which contain 1,869 slips. Eleven of these marinas contain launching facilities such as rail ramps or hoists. In addition, there are two government-owned launching ramps which can be used without fee.

It is estimated that recreational boating use has been increasing at a rate of about 10% annually, which is somewhat higher than the 5.9% growth rate of registered

boats in the region. It is expected that 500 to 700 additional moorage slips will be made available on the Washington Channel during the next couple of years.

It has been indicated that serious conflicts between recreational and commercial crafts generally do not occur, although isolated incidents of the failure of recreation craft to yield right-of-way to commercial vessels in restricted channels have been reported. These incidents are estimated to occur once every two or three weeks on the Potomac River on the reach between No. 6 buoy to the junction buoy at Haines Point.

Since now NWS Inventory data were available for recreational facilities in the Port of Washington, D.C., the base data collected from the telephone survey were used in the formulation of a base use level. It is expected that recreation boat use will equal 2,700 boats during a peak day in 1985, 3,600 boats in 1990. 4,800 boats in 1995 and 6,400 boats in 2000.

3. Port of Baltimore. The Maryland Port Administration was contacted but could provide no data on recreational boating or on conflicts between recreational and commercial navigation.

The Baltimore City Harbor Master stated that there are currently five marinas operating in the city and two public launching facilities, one of which is equipped with two hoists. Although the exact number of moorage slips was not available, it was indicated that all slips at the inner harbor marina are occupied, while the remaining four marinas have vacancies at the present time. No estimates were given of the number of boats put into the water at the two launching sites.

A memo prepared by the City of Baltimore Department of Planning concerning "Preliminary Analysis of the Economic Impact of the Middle Branch Park Plan" states that there are presently 340 recreational craft moored in various marinas. The memo also states that there is sufficient demand for boating within the harbor to justify the construction of 3,050 new slips and five new launching ramps.

According to the City Department of Planning, conflicts exist at present between recreational and commercial vessels on the northwest branch of the Patapsco River, which leds to the Inner Harbor. Plans are being developed to expand the Bridge Marina, which is now City owned, in conjunction with the redevelopment/rehabilitation of adjacent residential areas on the waterfront. This strategy of providing new and attractive mooring facilities in conjunction with residential redevelopment/rehabilitation is being contemplated for other areas of the city as well. Thus, the potential for future conflicts within the harbor is likely to increase. An advisory committee, comprised of commercial navigators, marina owners, representatives from the Corps of Engineers, the Coast Guard and other agencies, has been appointed by the Mayor to address these potential conflicts.

Since no recreational facilities data were available in the NWS Inventory, all base year data were based on the information collected from the telephone survey and the written material available. The low existing usage level of 335 recreational craft on a peak day is attributed to the fact that more attractive boating areas are available nearby, but not directly in the harbor. The high growth rate for boating demand within the harbor can be attributed to the efforts to revitalize and improve the aesthetic and recreational features on the harbor at present and in the future. Forecasted demand in 2000 is about 2,000 recreatinal craft on a typical peak day.

Port of New York. Both the Coast Guard and Port Authority of New York/New Jersey were contacted, but no information concerning recreational boating facilities, expansion plans or recreation-navigation conflicts could be obtained for the Port of New York. The boundary of the Port of New York is assumed to be the same as that of the Port Authority's jurisdiction in New York anid New Jersey, althought the NWS inventory data may include a much larger area.

Forecasts were based on the existing recreational boating facilities data available from the Inventory, although the numbers are highly suspect. Recreatio demand is forecasted to decline from 17,180 boats on a typical peak day in 1976 to 11,100 in 2000. The Port of New York is the only port included in this analysis which is expected to show a decline in recreational boating demand.

5. Boston Harbor. Boat registrations for 1979 indicate that there are 2k414 boats kept in the City of Boston and in surrounding areas which are generally considered to be part of the Boston Harbor area. It may be assumed that all of these boats remain moored in marinas or clubs during the boating season.

Based on information obtained from the United States Coast Guard's Marine Safety Office, recreation-navigation conflicts do exist in the harbor area, particularly in the vicinity of two sailing clubs. During the summer months, these clubs rent sailboats and sponsor races twice a week, involving 15 to 25 sailboats. The location of this conflict is in the main channel, at the northewest corner near the intersection of the Fort Point Channel.

Future conflicts are likely to increase as boating use is on the rise. Large new marinas are planned for the vicinity of Fort Point Channel, Old Boston Naval Yard, and Islands End on the Mystic River. Major expansion will take place at the marina located at the mouth of the Charles River.

Since an exact number of recreational craft was available from the Division of Marine Recreational Vehicles, this number was used as the base, although launching ramp data were taken from the NWS Inventory. Boatin use on a typical peak day is expected to increase from 2,290 boats in 1979 to 7,600 boats in 2000.

6. Erie Harbor. The Erie Harbor is defined as all of Presque Isle Bay. There are five marinas within the harbor with a total of 1,500 slips and four launching facilities.

High amounts of recreatinal traffic during summer months may cause potential conflicts between recreational and commercial vessels. Another potential source of conflict exists in the channel leading to the harbor. The channel, as it stands today, is only 75 yards wide and should be widened in order to avoid accidents, reduce delay time experienced by boaters, and accommodate the projected 5% increase in boats entering the harbor.

7. St. Clair and Detroit Harbors. Contacts were made with two offices of the United States Coast Guard (Detroit Harbor Office and Cleveland District Office).

There appears to be no clear distinction between the boundaries of the St. Clair Harbor and the Detroit Harbor and the St. Clair Harbor is sometimes interpreted to be the entire Detroit River. Generally, however, these two areas are treated as one even though the NWS Inventory treats them separately.

The number of marinas was estimated to total 10 along the two waterways combined. It was also estimated that 50 to 100 slips exist at each marina with a utilization rate of 90%. The total number of launching facilities for both waterways combined was estimated at four or five.

It was felt by the Coast Guard that recreation-navigation conflicts are basically non-existent. The Coat Guard was not aware of any plans to construct or expand recreation facilities along either of the waterways. Forecasts for these two harbors show a total incrase from about 1,500 boats on a peak day at present to 2,300 boats in 2,000.

8. Port of Seattle. Data pertaining to the number of marinas, slips and launching facilities in the Port of Seattle were not available from any of the sources contacted (Port Safety Branch of the Coast Guard and Washington Department of Parks and Recreation). Information was available on conflicts, however. According to the Port Safety Branch of the Coast Guard in Seattle, the most notable conflict in navigation occurs between fishing vessels and larger commercial ships. This conflict occurs infrequently, when the Stae of Washington authorizes the gill-netting of salmon. The only existing conflict identified between recreational craft and commercial craft occurs as a result of organized sailing regattas, comprising 300 to 500 boats, which take place at unpredictable frequency. While these regattas usually depart from Shilshole Bay, their course is largely dependent on wind direction prevailing before the event.

There are plans for a new marina on the Dawamish Waterway. These plans present a potential conflict to commercial navigation due to the limited water area and the extensive commercial navigation at this location.

Available data on boating use in the port is believed to be rather high and, coupled with the high growth rate in boat registration within the state, the forecasts

are also believed to be very high. Boating use is shown to increase from 6,458 boats on a typical peak day at present to over 80,000 in 2000. It is highly unlikely that such use levels will ever be realized in the Port of Seattle or elsewhere in the general vicinity.

9. Portland Harbor. Both the Port Authority off Portland and the Operations Branch of the Marine Safety Office were contacted for information, but no data were available concerning recreational use or facilities within Portland Harbor. It was, however, indicated that some recreation-navigation conflicts exist. No increase in conflicts is anticipated.

Since information was unavailable through the telephone survey and the NWS Inventory only provided number of slips, it was not feasible to make forecasts for Portland Harbor.

10. Oakland Harbor. The Oakland Harbor district was defined by the Department of Boating and Waterways, as the area extending from the Oakland Bay Bridge to San Leandro. It is estimated that there are 11 marinas, 2000 slips and two launching facilities within the harbor. Slip utilization is at 100% with a two to three year waiting list.

No conflicts between recreational and commercial vessels were cited. It was mentioned that the Army Corps of Engineers is presently studying traffic problems in the harbor.

There are plans for the expansion of a marina at Embarcadero to provide piers for commercial and recreational fishing and an additional 150 slips. The completion date is set for 1983. There is also speculation that new marinas will be constructed in Alameda. Boating within the harbor is expected to increase as more slips are constructed.

Recreatioal boating within the Oaklanid Harbor is forecasted to increase from 1,580 boats on a peak day in 1979 to 3,000 in 2000.

11. Port of Sacramento. The Port of Sacramento was defined by the Port Authority of Sacramento as strictly a commercial port with no marinas, slips or

launching facilities. As a result, no recreation-navigation conflicts were identified.

This statement conflicts sharply with the estimated 13,000 slips provided in the NWS Inventory. Due to the discrepancy and the fact that no launching ramp data are available, it was impossible to forecast future boating use within the Port of Sacramento.

12. San Diego Harbor. The San Diego Unified Port District states that there are 11 marinas, 5,500 slips and four public launching facilities within the harbor. However, only 5,150 slips are utilized, with the remaining 350 slips believed to be too small for the boats requiring slips.

Minor conflicts within the harbor occur due to the high volume of traffic. Also, the southern end of the harbor is relatively shallow, causing some problems for boaters.

Plans for the harbor include the construction of 400 slips at an existing marina located at the foot of Fifth Avenue. The completion date is set for 1982. A project for the construction of 600 slips in Chula Vista is also being considered. It is anticipated that this project will be completed within three to four years. Plans of the Port Authority include a doubling of the number of existing slips within the harbor in the next ten years.

San Diego Harbor is experiencing greater growth rate than Los Angeles, Long Beach and Newport Harbors since the marinas in these other harbors are already filled to capacity. San Diego, on the other hand, has room to grow.

Boating use in San Diego Harbor is forecasted to increase from 4,022 boats on a typical peak day in 1979 to 7,600 in 2000. This growth seems quite reasonable based on the marina expansion and construction plans for the harbor within the next decade.

(f) Reporting Region and Segment Summary

Table VI-4 summarizes the results of the recreational demand forecasts by analytic segment and reporting region.

The region with the greatest amount of recreation use of the commercial waterways is the Upper Mississippi, with close to 37 million activity-days annually foreseen by the year 2000. However, this number represents only a very slight (1.6%) increase over the fifteen-year period beginning in 1985. This region also has by far the highest numbers of recreational craft passing through locks (owing in part to the high number of locks but also to heavy recreational use of these facilities). Here again, however, the magnitude of the expected increase is small.

The other facility which will receive extremely heavy use, according to the projections, is Buford Reservoir or the Chattahoochee River (Gulf Coast East Region), with over 50 million activity days anticipated by the year 2000. In this case rapid growth of facility use is expected, from a level of under 28 million activity-days in 1985. This represents and increase of 88% over the fifteen-year period or an average annual increase of 4.3%.

Those parts of the Ohio River region for which recreational demand was forecasted add up to roughly the same volume of activity as the Upper Mississippi. One segment alone, the Cumberland River, accounts for over 25 million activity-days by the year 2000, making it the second highest single segment in terms of future recreational use of the commercial waterways. It is closely followed by the Tennessee River at over 22 million anticipated activity-days.

The Arkansas and Verdigris system also will experience high recreational demand, at a level of around 18 million activity-days by the year 2000. Use of this system will continue to grow until about 1990 when it is expected to level off. The Columbia River system is next at about 15 million activity-days, showing a fairly steady growth pattern over the forecast period.

Table VI-4

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
1. UPPER MISSISSIPPI (27 locks and pools)				
Swimming	1,381,800	1,415,800	1,438,900	1,462,500
Boating	11,335,800	11,378,800	11,407,300	11,434,200
Fishing	9,497,400	9,560,000	9,618,700	9,721,300
Other	14,151,000	14,230,800	14,281,200	14,334,000
TOTAL Activity-days*	36,366,000	36,585,400	36,746,100	36,952,000
Rec-craft through locks	152,315	152,435	152,518	152,584
2. LOWER UPPER MISSISSIPPI (Pool 26)				
Swimming	1,136,700	1,209,200	1,274,400	1,341,000
Boating	1,213,900	1,233,300	1,250,400	1,266,800
Fishing	1,399,600	1,412,600	1,423,700	1,434,400
Other	2,665,800	2,730,500	2,790,000	2,843,700
TOTAL	6,416,000	6,585,600	6,738,500	6,885,900
Rec-craft through lock	210	211	211	211
3. LOWER MISSISSIPPI - NO FORECASTS MADE FOR THIS REGION				

NOTES: Total activity-days indicates the number of person-days of participation in each activity. It is, therefore, greater than the total number of user-days, since each user may participate in more than one activity on a single day.

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
4. BATON ROUGE TO GULF Ouachita Black and Red Rivers (4 locks, 5 pools)				
Swimming	245,600	249,200	249,700	250,200
Boating	613,700	249,200	614,300	613,800
Fishing	1,760,500	614,700	1,761,500	1,758,100
Other	1,943,400	1,950,900	1.958,500	1,957,900
4. Continued				
TOTAL	4,563,200	4,579,200	4,584,000	4,580,000
Rec-craft through locks	3,710	3,170	3,169	3,167
5. ILLINOIS RIVER (9 locks, 12 pools)				
Swimming	67,400	71,100	73,600	76,800
Boating	1,999,600	2,016,800	2,030,500	2,049,800
Fishing	5,785,500	5,857,200	5,885,900	5,943,700
Other	4,036,200	4,053,700	4,078,200	4,113,300
TOTAL	11,888,700	11,998,800	12,068,200	12,183,600
Rec-craft through locks	28,498	28,608	28,655	28,714
6. MISSOURI RIVER				
Navigation Pool				
Swimming	45,200	47,300	49,300	51,300
Boating	1,498,400	1,512,400	1,525,200	1,537,700
Fishing	1,259,300	1,264,400	1,268,900	1,273,200
Other	10,203,000	10,317,700	10,422,200	10,523,700
TOTAL	13,005,900	13,141,800	13,265,600	13,385,900

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Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
6. Continued				
Gavins Point				
Swimming	515,100	587,900	678,400	768,300
Boating	515,100	587,900	678,400	768,300
Fishing	1,030,200	1,175,800	1,356,800	1,536,700
Other	3,296,500	3,762,500	4,341,700	4,917,400
TOTAL	5,356,900	6,114,100	7,055,300	7,990,700
7. OHIO RIVER				
Upper Ohio (9 locks, 10 pools)				
Swiming	135,500	135,100	132,900	130,200
Boating	946,200	947,100	945,800	943,900
Fishing	622,900	620,200	614,500	607,600
Other	1,459,200	1,465,900	1,465,900	1,464,500
TOTAL	3,164,500	3,168,300	3,159,100	3,146,200
Rec-craft through locks	18,949	18,949	18,945	18,940
Middle Ohio (4 locks, 5 pools)				
Swimming	217,800	220,900	221,200	220,900
Boating	821,700	822,700	824,400	823,300
Fishing	261,500	262,400	262,800	263,000
Other	1,743,200	1,744,800	1,743,100	1,740,900
TOTAL	3,044,200	3,050,800	3,051,500	3,048,100

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
7. Continued				
Rec-craft through locks	16,906	16,912	16,935	16,938
Lower Ohio (III) (3 locks and pools)				
Swimming	49,900	53,600	56,400	59,300
Boating	806,100	817,900	827,000	835,800
Fishing	1,872,700	1,895,600	1,912,400	1,928,600
Other	3,049,000	3,119,600	3,174,900	3,228,800
TOTAL	5,777,700	5,886,700	5,970,700	6,052,500
Rec-craft through locks	9,746	9,769	9,788	9,805
Monongahela (9 locks and pools)				
Swimming	20,600	20,600	20,400	20,200
Boating	240,200	239,700	238,900	228,100
Fishing	34,500	34,600	34,400	34,200
Other	69,600	68,500	68,200	68,200
TOTAL	364,900	363,400	361,900	350,
Rec-craft through locks	13,225	13,220	13,212	13,
Allegheny (L/D #2)				
Swimming	15,700	15,800	15,900	16,0
Boating	87,700	87,900	88,000	88,
Fishing	21,300	21,800	22,000	22,2
Other	5,200	5,200	5,200	5,2
TOTAL	129,900	130,700	131,100	131,5

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
7. Continued				
Rec-craft through lock	8,123	8,127	8,130	8,1
Cumberland (6 locks, 7 pools)				
Swimming	2,481,800	2,596,400	2,653,200	2,706,700
Boating	3,929,600	3,949,200	3,949,500	3,945,100
Fishing	7,821,400	7,881,000	7,897,800	7,918,300
Other	10,494,600	10,614,400	10,658,700	10,689,300
TOTAL	24,727,400	25,041,000	25,159,200	25,259,400
Rec-craft through locks	4,704	4,713	4,719	4,726
Tygart Lake				
Swimming	150,100	174,800	207,700	242,70
Boating	196,300	228,600	271,600	317,30
Fishing	80,800	94,100	111,900	130,70
Other	958,600	1,116,100	1,326,300	1,549,30
TOTAL	1,385,800	1,613,600	1,917,500	2,240,00
8. TENNESSEE RIVER (10 locks, 11 pools)				
Swimming	408,500	426,900	437,000	446,500
Boating	3,272,600	3,430,600	3,450,500	3,341,700
Fishing	6,523,700	6,588,700	6,625,400	6,659,600
Other	11,760,200	11,977,600	12,110,900	12,240,700
TOTAL	21,965,000	22,423,800	22,623,800	22,688,600
Rec-craft through locks	22,728	22,874	22,900	22,814

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
9. ARKANSAS AND VERDIGRIS (17 locks, 19 pools)				
Swimming	2,481,800	2,596,400	2,653,200	2,706,700
Boating	2,893,500	2,955,200	2,943,700	2,928,600
Fishing	4,855,300	4,907,400	4,925,600	4,941,100
Other	8,003,600	8,047,300	8,033,800	8,015,700
TOTAL	18,234,200	18,506,300	18,556,300	18,592,100
Rec-craft through locks	23,477	23,519	23,535	23,548
Oolagah Reservoir				
Swimming	28,900	34,300	40,900	47,800
Boating	202,200	240,200	286,700	334,600
Fishing	1,617,800	1,921,400	2,293,100	2,676,400
Other	2,628,900	3,122,300	3,726,400	4,349,200
TOTAL	4,477,800	5,318,200	6,347,100	7,408,000
10. GULF COAST WEST - NO FORECAST MADE FOR THIS REGION				
11. GULF COAST EAST				
ACF System (4 locks, 5 pools)				
Swimming	675,600	712,800	736,000	759,100
Boating	882,000	887,400	888,800	889,400
Fishing	4,990,600	5,027,700	5,058,000	5,078,500
Other	5,644,400	5,676,800	5,673,500	5,663,800
TOTAL	12,192,600	12,304,700	12,356,300	12,390,800
Rec-craft through locks	4,784	4,782	4,774	4,764

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
Buford Reservoir				
Swimming	3,944,300	4,997,500	6,191,900	7,513,000
Boating	6,096,500	7,597,200	9,450,900	11,467,200
Fishing	3,784,000	4,715,500	5,886,100	7,117,600
Other	14,085,000	17,552,300	21,834,700	26,493,200
TOTAL	27,909,800	34,842,500	43,343,600	52,591,000
Port of Tampa				
Peak day rec-craft	2,476	4,343	7,621	13,371
12. TOMBIGBEE/ ALABAMA-COOSA/ BLACK WARRIOR				
Alabama-Coosa (3 locks, 4 pools)				
Swimming	356,000	345,200	326,600	307,000
Boating	2,841,100	2,825,400	2,792,800	2,744,700
Fishing	3,718,700	3,655,400	3,545,300	3,471,500
Other	3,406,200	3,373,000	3,312,600	3,214,000
TOTAL	10,322,000	10,199,000	9,977,300	9,737,200
Rec-craft through locks	1,269	1,262	1,251	1,232
Black Warrior (6 locks, 7 pools)				
Swimming	129,200	129,800	127,800	125,700
Boating	1,365,200	1,368,700	1,366,700	1,364,000
Fishing	3,416,800	3,428,800	3,081,800	3,081,300
TOTAL	7,972,700	8,008,600	8,000,200	7,988,100

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
12. Continued				
Rec-craft through locks	3,290	3,290	3,287	3,284
13. SOUTH ATLANTIC COAST				
A & C Canal				
Swimming	0	0	0	0
Boating	73,700	74,800	75,700	76,600
Fishing	39,100	39,400	39,600	39,900
Other	100,000	102,300	104,200	106,000
TOTAL	212,800	216,500	219,500	222,500
Rec-craft through locks	2,462	2,470	2,476	2,482
Port of Washington, D.C.				
Peak day rec-craft	2,709	3,608	4,806	6,402
Port of Baltimore[1]				
Peak day rec-craft	562	864	1,330	2,046

[1](includes only City of Baltimore and not surrounding counties)

Port of New York				
Peak day rec-craft	14,589	13,332	12,165	11,109

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
15. NORTH ATLANTIC COAST				
Port of Boston				
Peak day rec-craft	3,230	4,302	5,780	7,632
16. GREAT LAKES				
Erie Canal (Lock #23)				
Rec-craft through locks	5,960	5,969	5,976	5,983
Erie Harbor				
Peak day rec-craft	1,712	2,174	2,762	3,509
St Clair/ Detroit Harbor				
Peak day rec-craft	1,753	1,916	2,095	2,290
17. WASHINGTON/ OREGON COAST				
Seattle Harbor				
Peak day rec-craft	16,654	28,189	47,716	80,767

Table VI-4 (Continued)

Recreational Demand Forecasts

REGION	1985	1990	1995	2000
18. COLUMBIA RIVER (8 locks, 9 pools)				
Swimming	831,100	852,900	872,200	891,
Boating	2,457,500	2,470,300	2,478,900	2,486,
Fishing	2,191,500	2,201,800	2,207,700	2,212
Other	10,072,500	10,412,800	10,184,000	19,218,
TOTAL	15,552,600	15,667,800	15,742,800	15,809
Rec-craft through locks	2,178	2,177	2,175	2,
19. CALIFORNIA COAST				
Port of Oakland				
Peak day rec-craft	1,897	2,187	2,575	2,9

20. ALASKA - NO FORECASTS MADE FOR THIS REGION

21. PACIFIC - NO FORECASTS MADE FOR THIS REGION

22. CARIBBEAN - NO FORECASTS MADE FOR THIS REGION

The Missouri River, the Illinois Waterway, and the main stem Ohio River have approximately comparable forecasted levels of demand (13, 12 and 11 million user-days, respectively). There Southeastern river systems will have fairly heavy recreational use: the Apalachicola-Chattahoochee-Flint, the Alabama-Coosa, and the Black Warrior systems. The ACF system (not including Buford Reservoir) is expected to be very stable at about 12 million activity days per year. Demand on the Alabama-Coosa is expected to decline somewhat, from 10 million activity-days in 1985 to nine million in 2000. The Black Warrior system is expected to show a slight increase to 1990 and a slight decline thereafter, hovering in the neighborhood of eight million activity-days per year. (This figure does not include recreation demand forecasted for the Tennessee-Tombigbee Waterway, which will presumably be generated during this period.)

Comparable levels of recreation demand are expected at Gavins Point (eight million activity days by 2000), Oolagah Reservoir (seven million activity-days), and Pool 26 on the Lower Upper Mississippi (seven million activity-days). The Ouachita, Black and Red system will have substantially less (between four and five million activity-days). Tygart Lake on the Monongahela is the least significant of the high recreation demand areas, with an anticipated annual demand of around two million activity-days by the year 2000.

Lockage of recreational craft is by far the most significant on the Upper Mississippi (more than 152,000 craft per year passing through 27 locks, for an average of over 5,000 craft per lock). Heavy recreational use of locks is also expected on the Illinois Waterway, the Arkansas and Verdigris system, and the Tennessee River. Each of these regions will generate a lockage demand amounting to between 20,000 and 30,000 recreational craft annually.

The heaviest use of a single lock (excepting the Upper Mississippi) is found at Lock No. 2 on the Allegheny River, with over 8,000 craft annually. The Ohio River system generally accounts for a high degree of lockage demand, with nearly 19,000 recreational craft on the Upper Ohio, nearly 17,000 on the Middle Ohio, and over 10,000 on

the Lower Ohio (including those segments for which recreational craft lockage demand was not specifically forecast). This region also has relatively high use of individual locks, with an average demand of about 3,000 recreational craft per year at each lock.

Much smaller levels of lockage demand are attributable to the Monongahela and Cumberland Rivers, although the nine locks on the Monongahela generate a total of about 13,000 recreational craft passages for an average annual demand exceeding 1,000 craft per lock. Given the very high anticipated demand for pool recreation on the Cumberland River, it is interesting to note the relatively low level of demand for recreational craft lockage on this segment. The pattern here seems similar to that observed on the ACF, Alabama-Coosa, Black Warrior, and Ouachita, Black and Red systems. It appears to be related to the greater preponderance of fishing as a reason for boating activity in these regions.

Quite low levels of recreational lockage demand are forecast for the A & C Canal and the Columbia River system. In general, the volume of recreational locakge demand is expected to change very little over the forecast period at all of these facilities.

A sample of ports where recreational facilities are provided and where there is a relatively high volume of commercial traffic was studied in selected Coastal/lake regions. Data were obtained for nine ports. These data show Seattle, in the Washington/Oregon Coat region, to be the port with greatest anticipated recreational use in the future. New York Harbor, in the Middle Atlantic region, has themost recreational use at the present time, but this is forecasted to decline in the future. The highest expected growth rate is found at Tampa Bay, fairly closely followed by Seattle.

The ports of Washington, D.C. and Boston Harbor have quite similar patterns. Both will have around 3,000 recreatinoal craft out on a peak day in 1985 and this is expected to increase to about 7,000 craft in 2000, representing a moderate growth rate. Baltimore Harbor has a low number of recreational craft at the present time but

this is expected to increase at a rapid pace and to amount to over 2,000 craft on a peak day in the year 2000. This projection refers only to recreational activity within the harbor itself; it does not include any of the nearby areas outside of Baltimore City jurisdiction.

Recreational use of Erie Harbor in the Great Lakes region is growing at a moderate pace, from about 1,700 boats in 1985 to 3,500 in 2000. St. Clair-Detroit in the same region is starting at approximately the same level but is expected to grow more slowly, only reaching recreational demand levels of 2,300 craft by 2000. Finally, Oakland Harbor is also growing at a relatively slow pace and is expected to reach 3,000 craft on a peak day in 2000.

These data are not complete and they often raise more questions than they can answer. It would seem that the anticipated growth in boating demand (based on boat registration statistics) often cannot be accommodated within existing port facilities. When that happens, the recreational use is generally pushed out of the port area. This effect may be viewed as negative by recreational boaters, but the effective separation of uses also provides a benefit to both uses by relieving port congestion and minimizing the risk of accidents.

In summary, recreational demand forecasts have been made for all regions, segments and facilities where current use levels and/or conflicts indicate the potential for significant future recreation-navigation interactions. The inland waterway systems are fairly well covered by the available data. Analysis of these data show that the Upper Mississippi, the Ohio River system, the Illinois Waterway, the Missouri River and the Arkansas-Verdigris system are likely to be the focal points for future concern. Lesser, but still significant, future use levels are predicted for the ACF, the Alabama-Coosa and Black Warrior, and the Ouachita, Black and Red groups. Buford Reservoir is the most recreationally important reservoir authorized for navigation releases, though Gavins Point and Oolagah are also significant.

Much less is known about present and future recreation patterns in the coastal and lakes regions. The available data indicate heavy recreational use that is generally well separated from the commercial waterways system. The only major areas of concern are those specific geographical areas where recreational and commercial craft must compete for limited amounts of space, as in coastal canals, access channels, and in the vicinity of ports and harbors. More work needs to be done to adequately document the nature of interactions in these areas and to develop a comprehensive framework for predicting future interactions from the available data.

CONCLUSIONS

Recreational use of the commercial waerway is varied and extensive. Recreational use of navigation pools and reservoirs is reasonably well documented, while free-flowing rivers, lakes and coastal segments are less well covered by the current data systems. Interactions between recreation and commercial navigation occur most frequently in pools and channels, at locks and dams, and in ports and harbors. Reservoirs subject to navigation releases also offer a potential arena for future conflict between recreation and navigation interests.

(a) Current Recreational Use of the Waterways

High levels of recreational use characterize the Upper Mississippi, the Tennessee and Cumberland Rivers, the Arkansas-Verdigris system, the Great Lakes and the Middle Atlantic Coast. Several smaller river systems show moderately high levels of recreation use; this includes the Missouri, the Ohio, the Black Warrior and Tombigbee, Alabama-Coosa and ACF groups, the Ouachita Black and Red Rivers, the Illinois Waterways, and the Upper Columbia/ Snake Waterway. High levels of recreation use undoubtedly occur on other coastal segments but are not reflected in the existing data. Reservoirs have extremely high recreation use which may be sensitive to variations in water level.

Recreational use is recorded in terms of user-days devoted to varieties of water-based or water-enhanced activities. Four main groups have been established for the purpose of analyzing interactions with commercial navigation. These include boating, fishing, swimming and other water contact sports, and land-based activities such as sightseeing, hiking, picnicking, and so on. Recreational boating and fishing are often closely associated, particularly on the larger pools in the southern part of the country. Swimming and other water contact sports are limited by water temperatures, water quality, and safety considerations. Land-based but water-enhanced recreation is very important at all Corps facilities, particularly those in or close to urban areas.

While recreation studies and analyses are often carried out by agencies other than the Corps, it is difficult to disaggregate such studies in order to distinguish between recreational use of the commercial waterway system and recreational use of other water resources. In some areas, Corps recreation planners participate with other agencies in comprehensive regional planning activities to meet water recreation needs. This approach has proved fruitful in making the most efficient use of all recreation resources and in mobilizing community support for Corps recreation initiatives.

(b) Current Conflicts Between Recreation and Commercial Navigation

Data on current conflicts were solicited from Corps personnel, the United States Coast Guard and other agencies, commercial shippers, and recreation groups. In general, the level of perceived interactions between the two uses is low. The National Water Assessment concludes that recreation/navigation conflicts are insignificant compared to recreation conflicts with other water uses such as energy, agriculture, and industry. However, the recreational value of water resources is closely linked to the preservation of environmentally sensitive areas, such as fish habitats, wetland areas, and coastal zones. Recreational boating is recognized as a constraint on navigation at points of congestion such as locks and fleeting

areas. Recreational facilities also compete with commercial uses for valuable shorefront property. Thus, the perspective of this national assessment is that recreational demand is becoming a constraint on commercial navigation rather than the reverse.

Interviews with Corps personnel identified the following types of conflicts on the commercial waterways system:

1. congestion involving both commercial and recreational craft at locks and dams.

2. congestion involving both commercial and recreational craft at ports and harbors.

3. impacts of dredging activity and dredged material disposal on recreational activity and potential.

4. conflicts between competing uses of surface water space (fishing vs. fleeting) and associated shoreline land uses.

5. impacts of wave action caused by commercial tows on shoreline land and water uses.

6. potential impacts of variation in reservoir or lake levels due to water withdrawals or releases for navigation purposes.

These conflict areas also offer an opportunity to enhance complementary use by taking steps to avoid or minimize conflict situations and thereby making the waterway system available to all potential users.

United States Coast Guard accident data were examined to see if they can serve as an indicator of recreational/commercial conflict and congestion. It was found that recreational/commercial accidents form only a small part of all boating accidents and that the reporting system does not lend itself to detailed identification of conflict areas. Such accidents are most commonly reported on coastal segments, although fatalities are more likely to occur in accidents on river segments.

It is concluded that conflicts occur principally on controlled segments or in the vicinity of Corps facilities such as ports and harbors. Conflicts are generally more intense near urban areas where many competing water uses come into play. At the present time, major conflict areas include the Upper Mississippi, the Ohio River system, the Arkansas and Verdigris, the Columbia River, Chesapeake Bay and San Francisco Bay. Reservoirs associated with commercial navigation present the potential for future conflict, but little conflict is experienced at the present time.

(c) Analysis of Future Recreation-Navigation Interactions

Recreation/navigation interactions generally involve conflict between specific recreational activities and specific navigation activities in a particular setting. From the comparative analysis of case studies, it appear that four major categories of recreation activity should be treated. These include:

- Boating and water skiing.
- Fishing.
- Swimming.
- Shore-based recreational uses.

The categories of navigation activity which impinge upon recreation uses are identified as follows:

- Planning and design of facilities.
- Operation and maintenance of facilities.
- Commercial navigation activities including:
  (a) Traffic levels.
  (b) Fleeting activity.
  (c) Port activities.

Certain planning issues cut across the range of facility types and need to be addressed on a system-wide basis. The results will not lend themselves to a regional analysis but rather will be appropriate to the institutional analysis of the waterways development planning process as a whole. Other design issues, particularly those pertinent to the location and capacity of facilities, can be addressed at a site-specific level and directed toward the mitigation of present or potential conflict situations.

Most of the existing conflicts arise not from construction activities but rather from the operation and maintenance of existing facilities and/or the growth of commercial or recreational activities on the existing system. Some of these issues it two, three or more groups of waterways users against each other in competition over various elements of the waterway resource: channel depth, surface area, shoreline space, water quality, fish and wildlife, and aesthetic values. The allocation of these resource elements to one or another use creates constraints on competing uses. For this reason, the allocation process is essentially a political process in which the needs and desires of different user groups are weighted against the intensions of society as a whole (as expressed in the enabling legislation for a particular project and overall Corps policy).

Impacts of navigation activity on recreational use may be either direct, as in the case of recreational vs. commercial use of locks, or indirect, as in the case of impacts on fish populations indirectly affecting recreational fishing activity. The intial focus of this analysis is on direct conflicts which can be forecast from a knowledge of future recreational and commercial navigation activities. The analysis of indirect impacts depends upon the conclusions of other relevant parts of the NWS.

A major theme in the analysis is the sense of conflict engendered by the disparities between authorized and actual uses of the system. Only recently has recreational use been incorporated into the enabling legislation for new waterways development projects. Older projects, constructed for commercial navigation or other purposes, have in some cases been virtually taken over by recreation

users. Where commercial navigation remains or has become a significant use, recreational conflicts are now likely to occur. Uncertainty regarding authority to serve recreation needs seriously limits the ability of project planners and managers to deal with the situation in a constructive and comprehensive manner.

One consequence of this uncertainty regarding the appropriate role for the Corps in providing recreation opportunities is that regional recreation needs and resources are sometimes not adequately taken into account in the planning and design of new facilities. Performance in this are is higly variable from one Corps district to another. While some districts have developed a constructive and comprehensive approach to planning that involves detailed forecasting of recreation requirements, others find it difficult if not impossible to integrate this issue into the planning and decision making process. The Corps needs to first see itself systematically as a participant in the arena of recreation service provision, and then to develop and disseminate appropriate planning procedures.

Much can be done at the planning stage to mitigate or enhance impacts of navigation activities through the use of location, capacity and design criteria. For example, when larger locks are required to accommodate new types of commercial craft, smaller locks can be convered to the exclusive use of recreational craft. Other technological alternatives for passing recreational craft through locks have been examined. Creative use of dredged material result in the generation of new land for recreational or commercial purposes. Design alternatives such as fish ladders or notched dikes can be used to mitigate or enhance the impact of new facilities on the existing ecosystem.

Generally, however, technological innovations are less likely to be useful as a mitigating measure for present or potential conflicts than institutional innovations that permit greater flexibility in the use of facilities to meet multipurpose needs. Included in this list would be a variety of scheduling options, regulatory changes, use of permit granting powers, and public participation in the decision making process. Such approaches are likely to be

effective in resolving conflicts that occur primarily under peak load conditions. Recreational use of the waterways exhibits a high degree of seasonal, daily and even hourly variation. Thus it is highly amenable to this type of negotiated solution.

A final planning and design issue concerns the use of land resources associated with the waterways system. As commercial traffic grows, shore-based urban and industrial uses will tend to expand. Space will be needed for port facilities, warehousing, drydock, and cargo loading facilities. Induced land traffic, as well as the operations of vessels at rest, will contribute to the decline of air and water quality in the immediate vicinity. These uses may compete directly with recreation for desirable shoreline access and for the use of environmentally valuable resources.

Some case studies suggest that more land along the waterways should be acquired in order to exercise maximum control over shoreline land uses. This is increasingly necessary in order to assure adequate space for future maintenance operations. This policy would create an opportunity for the Corps to develop a *comprehensive* approach to land use planning for multipurpose use, including not only recreation but also environmental protection and commercial and industrial uses. Where further land acquisition is not feasible, the Corps can still exercise some degree of control over shoreline land uses through its permit granting powers.

The case of the Tennessee-Tombigbee Waterway illustrates what can happen when recreation is accepted as an authorized project purpose and is taken into account from the earliest stages of project planning. Recreation needs and alternate opportunities can be evaluated, and project resources can then be allocated to meet needs in the most effective manner. Mitigation measures such as the use of dredged material to create recreation areas can be incorporated in the project design. The success of the project in avoiding future conflicts depends on the accuracy of the forecasts of recreational and commercial use and on the adequacy of system design standards to meet these demands.

Interactions between recreation and navigation activities on the waterway system are just beginning to be taken into account at the planning and design stage. Activities undertaken to meet commercial navigation needs have in the past provided enormous benefits to recreation, as well as creating constraints in some cases. Future planning and design activities can be more systematically oriented to eliminating constraints and enhancing recreational benefits through acceptance of the Corps' legitimate role as a recreation service provider and the development of a more comprehensive set of planning procedures and design criteria.

The construction, operation and maintenance of facilities for commercial navigation also benefits recreationists, particularly recreational boaters, to the extent that public access is permitted and the two uses do not come into conflict. Potential impacts of these navigation-related activities on recreation are discussed by type of facility below (see Figure IV-A for an impact summary).

Large volumes of commercial and recreational traffic in relation to system capacity result in congestion. Congestion may occur at any point on the system, but it is most apparent at bottlenecks such as locks and dams, narrow channels, low bridges, river mouths, and ports and harbors. To predict future congestion conflicts, it will be necessary to forecast recreational and commercial traffic in terms that can be compared to measures of system capacity, and to identify the location of present and potential bottlenecks.

Congestion between recreational and commercial boats is strongly associated with safety hazards as measured by reported accidents involving both types of craft. However, such accidents are rare in comparison to accidents between recreational craft, which also occur in congested areas and have little to do with the volume of commercial traffic. Generally, recreational and commercial vessels avoid each other where possible. Actions to reduce accidents could include eliminating bottlenecks through major structural changes (e.g., channel widening), but this relatively low-level conflict can probably be controlled

in most areas through improved traffic regulation (e.g., speed zones) and public education programs on boating safety.

Commercial traffic also generates demand for water space to be used for turning basins and for fleeting areas. Where water space is a scarce resource, this demand can create a major conflict with recreation use, particularly close to urban areas. Use of water space for fleeting activity is closely tied to shoreline land uses, and is generally incompatible with recreational use of both land and water. As the volume of commercial traffic grows, the need for space for fleeting areas and turning basis is likely to become a major design issue. Greater control ove shoreline land use is required if the Corps is to be in a position to satisfy both recreational and commercial interests on this issue.

Finally, growing commercial traffic volues are likely to increase conflicts in the vicinity of ports and harbors, unless new ports are created at a comparable rate of growth. Commercial traffic contributes to air and water pollution and may create a safety hazard for recreational users of the waterway. The growth of urban and industrial land uses, which in turn will create population concentration and income growth, have resulted in increasing demand for recreational facilities. Future port development or expansion should be planned with these interactions in mind, so that adequate space can be reserved for urban and industrial uses in the vicinity of the port, and at the same time compensating recreational facilities can be constructed elsewhere in the urban area.

A notable feature of the analysis of recreation-navigation interactions is the absence of present conflicts on the Great Lakes, despite high volumes of both commercial traffic and recreational activity. It seems that water and shoreline space on the Great Lakes is sufficient to accommodate both types of use, and conflicts are avoided by the physical separation of uses. Commercial traffic follows known routes and stays well out from shore except in port approach channels or in the vicinity of locks (St. Marys River). Thus, recreational boaters can easily avoid commercial vessels, and fishing, swimming, and shoreline

uses are relatively unaffected. The past major deterioration of water quality in Lake Erie (only partially attributable to commercial traffic) seems to have been reversed through regulatory measures, and the lake is once again becoming a significant recreational resource. A similar description (lack of conflict due to separation of uses) seems to apply to bay areas exclusive of ports and channels.

(d) Impacts of Future Technology Changes

The possibility that future technology changes might affect future recreation-navigation interactions was also considered. Construction of additional facilities would, of course, create additional recreation opportunities. The types of activities affected and the magnitude of the impact would depend to a great extent on project design characteristics. However, there is little reason to suppose that new technologies would be adopted simply in order to enhance recreational benefits.

The technology of facility operation in the engineering sense seems unlikely to change in response to changing needs, is the set of organizational priorities and procedures governing the application of present technology (e.g., restricted recreation craft lockage times, information systems and mooring areas).

New developments in cargo handling facilities may change the patterns of activity in ports and harbors. Unless these changes significantly affect the waterway use itself, they will not have a significant effect on recreation-navigation interactions in this setting.

A decline in the volume of dredging may negatively affect both commercial and navigation, though it may also have beneficial effects on water quality, fish and wildlife that would offset the negative boating impact. New technologies of dredged material disposal offer the promise of creating new lands for recreational or industrial use. Bank protection and channelization works may be more extensively employed in the future to maintain

depths and to reduce the need for dredging. If planned in conjunction with recreation development of the shoreline, such projects could have a beneficial impact on recreation use.

Among recreational activities, boating seems to be the most susceptible to impacts due to technological change. Recent developments that have affected the pattern of boating include the development of the outboard motor, the use of fiberglass and other strong but lightweight materials in boat construction, and retractable centerboards for sailing craft. All of these developments have contributed to changes in the patterns of boat ownership, storage and use. The relative decline in the cost of boat ownership, or in other words, the increase in effective boating opportunities, has much to do with the fact that the rate of growth of recreational boating considerably exceeds that of the United States population and of per capita income as well.

The probable impact of higher future energy costs will be to accelerate the current shift away from motorized craft to sailboats and canoes. It seems likely that the share of recreational boating activity accounted for by these two types of craft will increase to small outboard boats as well. Since most non-motorized boating takes place on reservoirs, it seems likely that ethe demand for recreational boating on reservoirs would increase relative to the demand for recreational boating in navigation channels. Conflicts in navigation channels may also increase due to the lesser maneuverability of non-motorized boats and their greater susceptibility to wave effects.

However, it appears that no new water-based recreation technology will become an important water use or cause different pressures on navigation than the present operational and space conflicts. Thus, new technology trends in recreation will not be a factor in predicting future recreation-navigation interactions.

(e) Future Levels of Recreation Demand

Recreational demand was forecasted for all waterway facilities currently classified as having high recreation use. The forecasts provide complete coverage of the Upper Mississippi, Illinois River, Tennessee River, Missouri River, Arkansas and Verdigris, Ouachita Black and Red, Alabama-Coosa, Black Warrior, and ACF groups. They also provide fairly extensive coverage of the Ohio River system. Lake and coastal segments are less well covered with forecasts being made for selected ports and harbors.

Recreational demand forecasting was carried out for specific types of facilities and for specific recreational activities in each region. Forecasting was performed for 140 navigation pools distributed among 22 waterway segments. In general, the forecasted use levels appear to be rather conservative.

Growth rates predicted for swimming are somewhat higher than those of other recreation types. However, the number of swimming user-days for at each navigation pool is generally lower than the number of user-days for any of the other recreation types. The lower use rates are attributed to three major factors: availability of alternative swimming facilities, the negative effect of poor water quality on swimming use, and the fewer number of days during the year which are suitable for swimming.

Like swimming, approximately two-thirds of the pools experience an increase in boating and water skiing activity between 1977 and 2000. With the exception of one pool, all increases are less than 10% throughout the period. Almost all of the remaining one-third of the pools experience decreases in boating and water-skiing activity, due entirely to decreases in population.

More than 70% of the navigation pools experience an increse in fishing user-days during the 1977-2000 period. Most of the growth rates do not exceed 10% during this period, although certain pools do exhibit larger increases. For those pools experiencing losses in fishing use, the rates of decline are also generally less than 10%.

In general, the amount of land-based recreation activity which exists in the vicinity of navigation pools is far in excess of any other single recreation activity which actually takes place on or in the pools. There are three major reasons for this fact: "other" recreation is comprised of a variety of land-based recreation types, no special equipment is required to participate in some of the activities, and it has a longer recreation period during the year.

The forecasted changes in the number of recreational craft passing through locks are quite minor during the 1977-2000 period. In fact, in many cases the change is so minor that these locks and dams can be considered to experience virtually no change. The increase or decrease in number of recreational craft does not exceed 5% for any lock and dam facility by the year 2000.

Recreation demand was forecasted individually for the four reservoirs potentially affected by variations in water level. Recreational use is extremely high and still growing at Buford Dam (Lake Sidney Lanier). It is also high and still growing at Gavins Point (Lewis and Clark Lake). Oolagah Reservoir will have somewhat slower growth, while the least activity is expected at Tygart Lake. Corps managemen policies, reservoir location, and the presence of alternate water resources are all important factors affecting the rate of growth of recreational demand.

Recreational use of ports and harbors is the least well understood area in this analysis. Projections indicate rapid growth of boating activity on the Florida Coast and the Oregon/Washington Coast, moderate growth on other coastal and lake segments, and a potential decline in boating demand near the commercial ports of the Eastern seaboard. More work needs to be done in this area in order to identify factors associated with conflict and change.

Forecasts were not made for major ship channels and the three salt water barriers carrying high levels of recreational craft. It would appear that recreational use of commercial ship channels is largely limited to land-based uses. However, boating congestion may become a

concern in some areas not presently identified as conflict areas, such as Cape Cod Canal or the Houston Ship Channel. This possibility merits further examination.

Future recreational use patterns will not differ significantly from these found today on the commercial waterways system. The Upper Mississippi, the Ohio River system (especially the Cumberland River), and the Tennessee River will have the highest future levels of recreational use. The Arkansas and Verdigris, Columbia River, Missouri River, and Illinois Waterway will also experience major recreational demand. Buford Reservoir will continue to be one of the most heavily used of all Corps-operated recreational facilities.

Several southern river systems will have only slightly lower use levels: the ACF Alabama-Coosa, Black Warrior, and Ouachita, Black and Red Rivers. This will include the Tennessee-Tombigbee Waterway after construction is completed. Coastal and lake segments will undoubtedly experience heavy recreation use, but with effective separation of uses, this is not expected to generate significant conflicts with commercial navigation.

VII - BENEFICIAL EFFECTS OF NAVIGATIONAL PROJECTS

Corps navigation projects have had many beneficial impacts on other water uses. Some of these have been planned, as in the case of multipurpose projects to promote flood control, hydropower, irrigation, water supply, recreation and/or fish and wildlife. Other beneficial impacts have been created as a by-product of activities designed primarily to promote commercial navigation. The first category of benefits is only briefly examined in this section of the report as they are well known. The second category is treated in somewhat greater detail through five case studies presented below. Only beneficial effects are treated here, as negative effects or conflicts are covered in the preceding sections.

The first case study concerns the recreational benefits of controlling river systems, as exemplified by the Upper Mississippi. The second describes the benefits to fish and wildlife generated by channel alighment (and consequent creation of oxbow lakes) on the Verdigris River. The third case study considers the use of the Lower Mississippi. The fourth investigates the recreational benefits of port and harbor development on the Great Lakes, which is assumed also to apply to coastal segments. Finally, the socioeconomic impact of the integrated river basin development is examined in the case of the McClellan-Kerr Arkansas River Navigation Project.

METHODOLOGY

Field interviews with Corps personnel as well as documents and data from non-Corps sources were reviewed in order to establish the range of beneficial impacts experienced on Corps navigation projects in the past. This review focused on effects on other water uses arising out of projects constructed primarily for navigation purposes. Thus, at least two categories of impact, though common, were given only cursory attention. These were: (1) benefits to recreational boating arising from navigation improvement projects and (2) benefits to other uses arising out of multipurpose projects.

(a) Types of Activities

Five areas of Corps activity were identified from this review as having generated beneficial impacts on other water uses in the past. These include:

1. Water impoundment.

2. Channel alignment.

3. Dredging.

4. Port and harbor development.

5. Integrated planning for river basin development.

Out of several possibilities, one case study was selected in each of these areas of activity to illustrate the process through which beneficial impacts are generated by Corps activities.

(b) Types of Beneficial Effects

The beneficial effects of Corps navigation projects upon other waterway uses are numerous. They include the well known effects derived from authorized multipurpose projects, such as flood control, hydropower, water supply, irrigation, recreation and benefits to fish and wildlife. In addition, there are indirect effects, including the use of dredged material to create industrial sites, recreation home sites, wildlife habitats, and beaches. Corps prjects in channel alignment have in some cases generated significant benefits to fish and wildlife interests because of new habitats created by oxbow cutoffs. River training structures have also allowed riparian lands to be put to productive use by the agricultural sector. Finally, there are a broad range of socioeconomic and quality of life benefits which can be generally characterized as a spinoff from integrated river basin development.

Flood control is a benefit which is often compatible with navigation in multipurpose projects. Navigation projects which require a lock and dam create pools of varying sizes depending on the local topography. If the pools are of sufficient volume and a flexibility of stage adjustment exists, then significant flood control benefits may be generated.

Similarly, hydropower benefits are also compatible with navigation projects under certain hydrological conditions. Head differentials, storage volumes, and flow regimes are the significant hydrologic parameters. Some lock and dam projects, termed "pondage" projects, generate power even with small storage capacities by allowing fluctuations in water elevations within the ranges required by navigation interests. These fluctuations are usually accomplished on a daily basis. Other projects, termed "run of the river" projects, allow little fluctuation in water elevation and rely on guaranteed flow volumes to generate power.

The beneficial effects of navigation projects on water supply and irrigation require the same conditions as flood control projects; significant storage volumes and flexibility of pool elevations. Water supply and irrigation, being consumptive water uses, are compatible with navigation as long as the long term water demands remain in balance and do not increase to the point of being competitive with navigation requirements.

Recreation interests have benefitted enormously from navigation projects. Corps projects which impound water create pools which generally provide water conditions which are conducive to boating, swimming, fishing, and associated land-based activities, such as picnicking, camping, and sightseeing. For multipurpose projects which include recreation as an authorized purpose, the recreational facilities and operating procedures designed to meet the recreational needs are often quite extensive.

In many cases, where recreation is not an authorized purpose, significant benefits are nonetheless generated. Navigation projects are beneficial to recreational boating as well as to commercial shipping. Control over a water

resource may also improve the quality of other water-dependent or water-enhanced recreational activities in the area.

In a similar manner to recreation, fish and wildlife interests are often benefited by navigation projects which impound or regulate flows. Special recognition of fishery needs, particularly in regard to spawning requirements, is shown in certain project operation schedules. Incorporation of fish ladders in project design and/or the implementation of special gate opening schedules to serve fish and wildlife interests are examples of measures which may be taken to mitigate adverse impacts of facility construction and operation on previously present anadromous fish species. Wildlife habitats adjacent to waterways are also generally compatible with navigation.

Dredged material has been utilized to create landfill providing an extremely valuable benefit in certain cases, particularly in the creation of industrial sites near ports and harbors. The benefit is usually derived from the construction or expansion of the turning basin and related channels near a port. Characteristicalliy, ports are located in low lying areas and land free from potential flood damage is found only at a premium. Thus, the creation of land suitable for industrial purposes and conveniently located near shipping facilities is given a high assessed valuation. In some instances, dredged material has also created desirable recreational home sites.

Dredged material is also used for the creation or enrichment of beaches and marshlands for wildlife habitats. Both of these uses require quality control of dredged material grain size and an absence of pollutants. Suitable material is used either to supplement existing coastal beaches, which are subject to erosion, or to create new beaches, often along inland waterways, where beaches did not previously exist. Dredged material for marshlands is placed so as to develop a desirable mix of upland areas and ponds or estuaries. These types of development mostly occur along the intracoastal waterway segments.

Beneficial effects of navigation projects on fish and wildlife may also be derived from channel alignment works. Channel straightening of meandering rivers leaves an oxbow lake with slack water conditions, which improves the habitat for fish. Oxbox lakes are usually left with one inlet connecting to the main channel, which assures a natural fresh water supply. In some instances the oxbows were proved so beneficial to sport fishing interests that entrance channels are dredged periodically by the Corps to maintain boater access to the oxbow and to allow water exchange. Such dredging may, however, result in increased sedimentation in the oxbow.

A second beneficial effect of channel alignment projects may accrue to the agricultural sector. Bank stabilization and river training structures along the Missouri River have produced valuable farm land through a combination of sediment deposited behind river training structure and the reduction of risks from overbank flooding. These lands are particularly desirable in that the silts deposited often have excellent soil characteristics from an agricultural viewpoint. In addition, because of their proximity to the river, these lands may be naturally subirrigated.

Finally, navigation projects produce important benefits to the social and economic development of the surrounding communities. Regional growth is stimulated through the opportunities created in employment during both the construction and operation phase of a Corps project. Associated and secondary industries of the waterway transportation industry may then develop. Waterways have also had a positive influence on the quality of life index, which has become a major factor in industrial development decisions.

Some United States river systems have historically maintained an erratic or low level of habitat anid water quality. Corps navigation projects have materially enhanced the environment in many cases. Quality of life indicators are difficult to quantify, and many large projects have mixed impacts; however, the improvements in recreation and the environment in many cases provide a significant social benefit not only to the region but also to the nation.

ANALYSIS OF FIVE CASE STUDIES

In order to further examine the process by which beneficial impacts are generated, five examples were selected for further study. The Upper Mississippi River exemplifies the effects of water impoundment in creating opportunities for both water-based and shore-based recreation. Oxbow lakes on the Verdigris River are used to illustrate some of the beneficial effects of channel alignment. The use of dredged material to create industrial sites is described in the case of Greenville Harbor on the Lower Mississippi River. The benefits to recreational boaters of port and harbor development are illustrated by Corps activities on the Great Lakes. Finally, the overall socioeconomic impact of Corps participation in integrated river basin development is shown in several studies of the McClellan-Kerr Project on the Arkansas River.

(a) Recreational Benefits of Controlled River Systems

River regulation through the use of locks and dams, pools, and channels creates favorable conditions for many types of water-based and water-enhanced recreation. While quite different from the opportunities offered by wild and scenic rivers in an uncontrolled environment, the peaceful pools and long reaches of navigable waterways permit activities such as swimming and water skiing, as well as recreational boating, to be carried on in comparative safety. Locks and dams allow recreational boaters as well as commercial vessels to overcome obstacles to navigation and travel over considerable distances. Reservoirs created for navigation, flow regulation or other purposes are often most heavily used as new recreational resources. Finally, the vast expanse of accessible shoreline created by controlled river systems provides valuable opportunities for water-enhanced activities, such as picnicking, camping, hiking, photography, etc., often in the vicinity of urban areas where there is high demand for recreational space. The many benefits of controlled river system development are illustrated by events along the Upper Mississippi River's main stem.

1. Description of the Upper Mississippi. Many studies have been undertaken of the Mississippi River and its tributaries using different definitions of the area under study. However, many agree on the designation of that portion of the river running from Minneapolis, Minnesota to St. Louis, Missouri as the Upper Mississippi River main stem. The head of navigation and the northen limit of the area under Corps control is located just above Minneapolis, Minnesota. Analytic Segment 1 for the NWS terminates at the mouth of the Illinois River, just a short distance above St. Louis, Missouri.

A large number of locks and dams have been constructed on this segment in order to permit commercial navigation as far as Minneapolis. In addition, extensive bank protection works have been constructed along this segment and the channel configuration is controlled by periodic dredging. The design depth of the channel is nine feet at low water, and the channel width varies from 200 to 700 feet. Several major urban centers are found along this waterway, and it is heavily used by both recreational and commercial boat traffic.

2. Recreation Use of the Upper Mississippi. The significance of the Upper Mississippi as a recreation resource has led to a number of studies focusing on this use and predicting future levels of recreation demand. Some of these studies have been concerned primarily with recreational boating use and consequent congestion in the vicinity of locks and dams. Studies are also available on the recreational use of islands created from dredged material.

Relatively little attention has been paid to patterns of swimming, fishing, and shore-based activity, except where these have been associated with boating. However, detailed records on recreational use of pools have been kept by the Corps. Given the closely controlled configuration of this particular segment, it may be assumed that these statistics adequately describe the total pattern of recreation use related to the navigation project.

A survey of recreational boaters passing through locks on the Upper Mississippi during the summer of 1977 showed that each boat carries about four persons (on the average) on a round trip of well over 100 miles each way. Such trips involve passing through nine or ten locks and

take an average of three days. Nearly 40% of these long distance boaters camp on the dredged material islands, and another 15% camp on their boats, usually while moored at commercial marinas.

A large majority of these recreational boaters also enjoy swimming and picnicking during their trip. About 35% engage in water skiing and 25% go fishing. Other evidence indicates that fishing boats are much less likely to make use of locks and travel shrter distances than other types of pleasure craft.

Recreational and boating use exhibits distinct daily and seasonsal peaks. Traffic is heaviest during the summer and on weekends, especially in the vicinity of major urban areas. The survey data indicate, however, that some boaters are willing to travel substantial distances on the river in order to reach desirable recreational resources, such as the dredged-material islands. This is particularly true of larger boats, which tend to be moored at commercial marinas with direct water access. Small boats are more often taken by trailer to a launching facility; they make shorter trips and thus make relatively less frequent use of locks.

A detailed analysis of RRMS data for recreational participation by pool in 1976 on the Upper Mississippi (see Table VII-1) show that less than one-third of all recreationists are involved in boating on the lower part of the segment (Pools 11-26), while boating participation ranges from 45% to 75% on the upper part (St. Anthony Falls and Locks 1-10). In contrast, fishing is the most important activity in Pools 24 and 25. Water skiing, closely associated with boating, is important only on the upper part of the segment (below St. Anthony Falls). Shore-based activities also account for a substantial amount of recreational participation along this segment.

Extensive studies have been conducted by the Great River Environmental Action Team (GREAT), a consortium of state and federal agencies operating under the aegis of the Upper Mississippi River Basin Commission, to help develop a river resource management strategy.

Some of the findings of these studies, reported in the GREAT I Interim Report of March 1978, include:

Table VII-1

1976 Visitation to Pools on the Upper Mississippi River

Pool	Days of Use	Recreation Activity (%)			
		Boating	Fishing	Swimming	Water Skiing
Upper and Lower St. Anthony Falls	82,500	60	10	5	5
1	92,100	50	40	1	0
2	318,700	70	10	0	10
3	530,500	60	40	5	10
4	554,600	75	25	10	20
5	190,400	50	10	5	25
5A	256,700	65	40	10	10
6	560,500	60	20	10	20
7	333,000	60	20	15	20
8	478,700	50	25	5	10
9	498,200	50	20	5	5
10	371,400	45	10	10	10
11	642,800	30	50	2	2
12	1,392,400	30	50	2	2
13	3,025,600	30	50	2	2
14	749,900	30	50	2	2
15	419,000	30	50	2	2
16	1,153,200	30	50	2	2
17	653,400	30	50	2	2
18	735,800	30	50	2	2
19	1,855,400	30	50	2	2
20	145,200	30	50	2	2
21	2,418,100	30	50	2	2
22	1,112,700	30	50	2	2
24	502,419	21	35	26	9
25	1,396,300	21	35	26	9
26	3,939,200	21	35	2	9

SOURCE: Corps of Engineers Recreation Resource Management System Data. Reprinted in Midwest Research Institute, "Methodology and Forecasts of Recreation Use and Small Craft Lockages on the Upper Mississippi River," Final Report, Volume I, 1978, p.77.

(a) The sandy beaches created by depositing dredged material are the major attraction to many recreationists along the Upper Mississippi River.

(b) Over 12,000 acres of developed, and over 15,000 acres of undeveloped recreation lands (not including dredged material island/beaches) are in the study area. Other recreation resources include:

	Approximate Number
Boat launching lanes	200
Adjacent parking spaces	7,500
Marina slips	5,000
Private boat slips (not in marinas)	3,700
Individual camping units	2,000
Picnic tables	3,500
Designated hiking trails	135 miles
Designated horseback riding trails	30 miles
Designated bicycling trails	5 miles
Designated cross-country ski trails	30 miles
Designated snowmobile trails	40 miles

(c) The greatest deficiency is the tremendous shortage of multipurpose trails along the river.

(d) The potential exists to develop additional primitive boat access recreation areas within the river, on the islands, and/or on dredged material disposal areas.

(e) The rehabilitation of backwater areas and other productive habitats through development and implementation of maintenance techniques is feasible. Limited habitat rehabilitation measures have already been accomplished through the existing planning capabilities and authority of the Corps of Engineers.

As part of the GREAT study, in 1977, a survey was taken of recreationists using islands and beaches created

from dredged material on the Upper Mississippi. This survey found that slightly less than half of all users travel through locks in order to reach the recreation site, and a third start out from commercial marinas. Camping, swimming, fishing and wter skiing are significant activities at these sites in addition to boating.

An interesting aspect of this survey concerns the perception of complementary use. All users generally preferred to encounter other groups using the same type of craft as their own. Apart from this, houseboats and canoes were the most compatible with other types of craft, while cabin cruisers were seen as least compatibe due to their high speeds and large wakes. Canoeists were most tolerant of barge tows, perhaps reflecting the fact that barge tows stay in the channels while canoes generally travel along the shore. Cabin cruisers and runabouts were the least tolerant of barge tows, reflecting a possible competition for the same water areas. The number of powerboats also appeared to be closely related to user perceptions of crowding.

A detailed pool-by-pool analysis suggests that the recreational value and use of each site depends most crucially on accessibility, pool surface, shoreline space, water quality, and aesthetic values. Preservation of fish and wildlife is generally seen as a compatible use with recreation, although the two uses may come into conflict in certin circumstances.

3. Relation of Recreation Use to Navigation. A paramount public interest in commercial navigation on the Upper Mississippi has been expressed by the United States Congress since the nineteenth century, when the first river improvements were authorized. These initially consisted of removal of snags and other obstacles and supplemental channel maintenance. The first lock and dam on this segment was opened in 1917. In 1930, Congress authorized the undertaking of a major channelization project on the segment, including the construction of 26 locks and dams and the maintenance of a continuous nine-foot navigation channel from the mouth of the Missouri to Minneapolis.

The river valley contains steep hills and bluffs interspersed with bottomlands whose ponds, marshes, and backwater channels provide a variety of habitats that support an abundant range of fish and wildlife. In 1924, a

fish and wildlife refuge was established in this area. Construction of the commercial navigation channel altered hydrological patterns in the surrounding area by closing off many secondary channels and sloughs in order to assure adequate water depths in the main channel.

The resulting low flows in summer brought about a change in water quality with significant negative impacts on fish and wildlife. In response to public concern over this issue, several of the locks and dams were altered to change flow characteristics in ways that would enhance the preservation of the region's fish and wildlife resources (mainly through improved aeration).

The soils in the Upper Mississippi Basin are largely the result of glacial action which left deposits of sand and fine sediments throughout the region. The Mississippi River and its tributaries consequently carry a sediment load which contributes to silting and sand bar formation in the channel and requires periodic maintenance dredging to permit continuous commercial navigation. The sand and sediments are clean and somewhat fertile. When piled at a dredge disposal site in the middlie of the river, they form islands which quicckly acquire vegetative cover and become valuable resources for river recreationists. Such dredged material can also be used to create or replenish beaches along the shore.

Both the Corps of Engineers and the United States Fish and Wildlife Service have helped to develop points of public access to the river system, primarily to satisfy their own management needs. These access points are of high value to recreationists, however, since much of the shoreline is privately owned and inaccessible to recreation users. Figures on recreational participation at pools show steady growth since 1972, with the most rapid rate of growth occurring at pools adjacent to urban areas.

The operation of locks and dams primarily benefits a relatively small subgroup of recreational users, i.e., those recreational boaters using high-powered craft on relatively long river trips. Few canoes and sailboats make use of locks, and only a small share of fishing boats do so. However, all boaters benefit indirectly from the safety and security provided by the regulation of river flows. Those boats using the navigation channel (large power boats and sail boats) are also directly benefitted by channel maintenance activities.

To the extent that Corps activities in river regulation enhance water quality, a benefit is provided to all water contact sports, fishing, and shore-based but water-enhanced activities. The effects of water quality on recreational potential are shown by the patterns of participation at Pools 1 and 26, for example, compared to those at Pools 5 and 10. Boating use is relatively insensitive to water quality factors, while swimming, water skiing, and to a lesser extent, fishing are more dependent on water quality and flow characteristics.

4. Potential for Greater Beneficial Effects. The Upper Mississippi main stem is now a completely controlled river system. Little can be done to enhance recreational benfits by constructing additional facilities, with the possible exception of smaller locks dedicated to the use of recreational craft. Such facilities would be expensive to implement and would benefit only a minority of all recreation users. It appears that recreational traffic through locks is stabilizing as the locks near capacity limits. Future technology trends suggest that the demand for lockage of recreational craft may grow less rapidly than the demand for othertypes of recreational facilities in the future.

The cooperative relationship established between the Corps of Engineers, the Fish and Wildlife Service and other federal and state agencies involved in regional planning augurs well for the balanced development of river basin resources to meet shortand long-term recreational needs. Regulatory action by the Corps to reduce negative impacts of commercial navigation on water quality, fish and wildlife will further enhance the recreational value of the river and the surrounding region. Participation by the Corps in the forward planning activities of other agencies will increase the chance of promoting complementary uses and will facilitate the efficient allocation of Corps and other agency resources.

The use of dredged material to create islands and beaches can be continued as long as the dredged sand and sediments maintain acceptable quality for such use and as long as suitable sites can be found. Once a dredged material island has begun to acquire vegetative cover and animal life, it becomes more difficult to justify the continued placement of dredged material at the site. Beneficial impacts can be enhanced by planting bushes and trees and by designing island shorelines to maximize

access and acceptability for recreational boaters of different types. Picnicking, camping, and sanitary facilities could be added as use of the dredged material islands increases.

Perhaps the most significant contribution the Corps can make to meeting the regional recreation needs is to develop more and better access points for recreationists along the publicly owned shoreline, particularly near urban areas. Launching facilities and parking space continue to be needed at the major pools. The area around locks and dams can be developed as points of interest for shore-based recreation as well as for boaters waiting to lock through. This would involve provision of tie-up facilities, perhaps picnic tables and hiking trails, and basic sanitary facilities.

Little has been said so far about the interaction between recreation and historic and cultural features. The waterway system gives acces to many points of historic and cultural interest, dating back to the days when river transport was a major mode of travel. Provision of tie-ups, access trails, and signs would often enhance the recreational value of these resources at relatively little cost to the Corps.

(b) Oxbow Lake Benefits to Fish and Wildlife

The creation of an improved fish anid wildlife habitat often results from navigation projects as a result of channel alignment works. Channel alignment works are instituted to reduce the travel time along a meandering river. The time required to travel along such a river is significant not only because of the added distance above a straight line route, but also because of the difficulties encountered in steering around the numerous river bends. To reduce this travel time the Corps has sometimes constructed cutoff channels which eliminate the meander loop from the navigation channel, leaving a cutoff island and oxbow lake.

The aquatic habitat provided by oxbow lakes and the associated vegetation covering the shore line and the cutoff island have been found to provide significant benefits

to fish and wildlife along many waterway segments. The Verdigris River in the Arkansas Basin has been selected as a case study to exemplify the benefits which accrue to fish and wildlife interests as a result of activities related to navigation projects.

1. Verdigris River Description. The Verdigris River serves as the most upstream reach of the McClellan-Kerr River/Arkansas River Navigation System. The Verdigris is a relatively small river, 50 miles in length, which has been largely channelized for navigation purposes. The channel is designed to accommodate only one 105 foot-wide tow and therefore requires "passing zones" every two and one-half miles to allow simultaneous up-and-down stream movement of commercial craft.

The straightening of the Verdigris River has required 20 cutoff channels, producing 20 oxbow lakes. In addition, there are tow oxbows which developed naturally. The oxbow channels range in length from 2,000 to 24,000 feet. Most of the oxbows have had plugs placed in the upstream entrance to prevent sedimentation.

Although the oxbow lakes vary in size, they are typically about 500 feet wide and 20 feet deep. The banks support aquatic vegetation, such as cattails, which grades into sparse willows and other immature trees and finally is surrounded by a narrow band of mature trees. The undercover is grass and fallen logs. The convex side of the meander loop is normally steep and, within a short distance of the river, the land is cleared for farming.

The oxbows have become highly valued recreational sites for sports fishermen and provide the primary breeding sites for fish on the Verdigris. The fish inhabiting the Verdigris River are tolerant of high turbidity, high concentrations of dissolved solids, and a wide range of temperatures. The diversity of species in the oxbows is large and contains a better distribution between the species than the main channel, according to Corps studies.

The principal sport fish include bass, crappie, catfish and sunfish. The vegetation along the banks also supports a variety of mammals, reptiles and birds. There are several game species among the wildlife, including pheasant, quail and rabbits.

In order to facilitate recreational use of the oxbows, the Corps and the Oklahoma Department of Wildlife Conservation have cooperated to develop some of the oxbows specifically for recreation. This applies specifically to four oxbows, representing 14% of the total land area owned by the Corps along the Verdigris. Two oxbows, about 25% of the land area, have been allocated to fish and wildlife interests and are managed by the state. Nine oxbows fall under a multipurpose classification, which includes low density recreation use in some area. This constitutes 48% of the area. The remaining three oxbows are privately owned or utilized for industrial purposes at the present time.

The primary beneficial effect of the oxbows accrues to the recreation sector, especially to sport fishermen. Fishermen in the area are active in supporting the maintenance of the oxbows. Typically, fishing is from boats with access gained to the river using boat ramps. Land based recreation, such as picnicking and camping, is also important. Boating itself is less popular, but nonetheless, is practiced at times in the oxbow area.

2. Relation of Fish and Wildlife Benefits to Navigation. The benefits to fish and wildlife are indirect benefits in that the cutoff channels privide oxbow lakes, which can be exclusively reserved for recreation, fish and wildlife interests. With navigation confined to the main channel, the oxbow habitat can be managed to maximize fish production. The reduced velocities and generally stable aquatic environment of the oxbow provide better conditions for fish spawning than open river conditions. Further, there is no spatial conflict between recreational boats and commercial ships since the fishermen are removed from the navigation channel.

It is generally believed that the oxbow habitats created by the cutoffs provide better sports fishing conditions than the preproject conditions of the naturally meandering river. While there have been several studies showing the present fish populations of the oxbows, which are considered excellent, there are no available preproject studies on the Verdigris - Arkansas River for comparison. Related parameters such as stream velocity, sediment load, temperature, depth, and habitat indices, including substrate material and riparian vegetation, indicate general improvement in the oxbow habitats for most fish species on the Verdigris River.

There is a natural tendency for the oxbows to silt up at their entrances. This has required the Corps to dredge periodically at the downstream entrance channel to maintain the free flowing connection between the oxbow and the main channel. Continued maintenance by the Corps is necessary to maintain the entrance channels in order to provide optimum oxbow conditions.

A final planning option, which the Corps may utilize to maximize beneficial effect of oxbows, is to develop a land use plan which is acceptable to recreation and industrial interests. It is recognized that this is not a simple task. The Verdigris River, for example, has been the scene of a major conflict involving the needs of the waterway transportation industry for fleeting areas (which can only be provided by the oxbows on the Verdigris River) and the fish and wildlife interests, who want the areas reserved for recreation purposes. In order to reduce such conflicts the Corps needs to provide leadership in planning which will provide a satisfactory and equitable compromise to all interests. Advanced recognition of future needs of waterway users and provision for those needs through integrated land and water use plans is a difficult but necessary task in order to maximize the benefits of the waterway resource.

(c) Dredged Material Benefit to Industrial Sites

Dredging, and the disposal of dredged material, has been the subject of many intensive studies by the Corps. The disposal of dredged material has often been found to be a difficult task in locations where the material has no accepted value. However, in the creation of industrial sites, dredged material has proved to be a valuable resource in many instances. The use of dredged material to create industrial sites as a result of port construction and expansion is a particularly significant benefit. Greenville Harbor, Mississippi has been selected as a case study to exemplify this beneficial effect.

1. Greenville Harbor Description. Greenville Harbor is located on the Mississippi River a few miles below the confluence of the Arkansas River in the Vicksburg district (Upper Lower Mississippi River, analytic segment No. 5). Historically, Greenville has been an

active commercial port. Many towboat companies have established Greenville as their home port because of its central location on the Lower Mississippi River. Industries have located in Greenville in order to take advantage of cost savings inherent in water transportation and to contribute to the economic and demographic growth in the area.

At the present time, all suitable waterfront sites in the Greenville area are being utilized or are committed to development. Figure VII-A shows a map of Greenville with the associated harbor. The principal users in the Greenville reach are towing, oil, grain, gravel, and lumber firms.

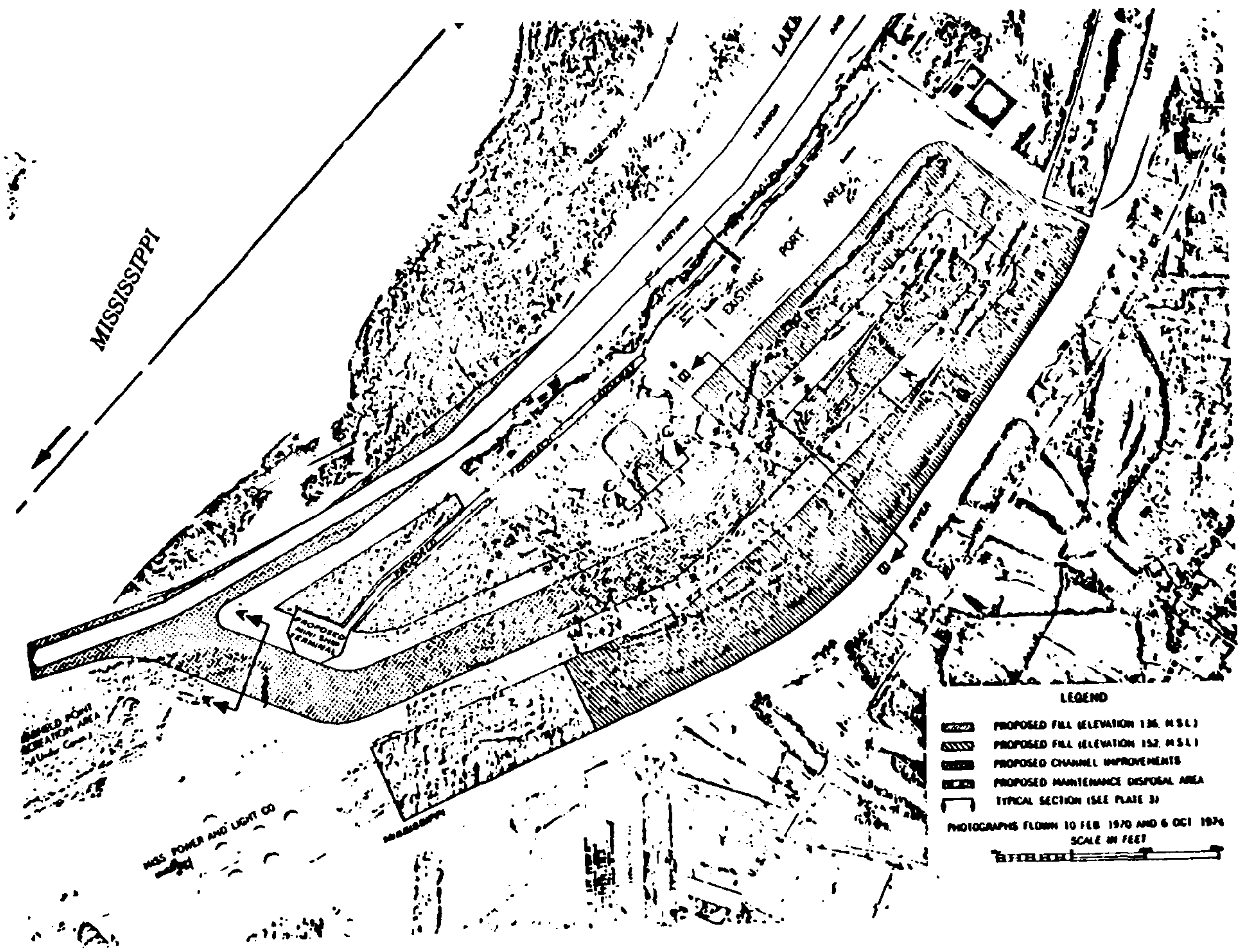
Material from the Greenville harbor improvements would be used to provide 360 acres of adjacent landfill for industrial development. Of the total area, 306 acres would be available for industrial development and fifty-four acres of the project lands would be utilized for service-related facilities. The land in the project area was valued at $500 per acre, and the development costs, which include a paved road, railroad, powerline, water line, sanitary and drainage facilities, were estimated at $4,300 per are. Subtracting the development cost from the net increase in market value produced a net increase in value of $2,600 per acre and a total net enhancement of close to $800,000 for the new industrial sites.

2. Relation to Navigation. The disposal of dredged material is one of the more difficult problems faced in Corps operations. In those instances where dredged material can be placed to advantage it is a significant improvement over most dredging operations. In the case of Greenville Harbor, which is typical of most ports and harbors, increased waterway traffic reached a level whereby congestion, both in the channels and dockside, required expansion of the facilities. The proposed volume of dredged material for expanding the turning basin and related channels is enormous. This material will serve to create riparian land upon which offices, warehouses, factories and other infrastructure related to the waterway shipping industry, will be built.

There are implicit measurable relationships between navigation and the beneficial efects of dredged material which is utilized for creating industrial sites. The sale value of the industrial land created reflects the

Figure VII-A

Greenville, Mississippi Port Plan



value of the dredged material, which in turn is a reflection of industries' willingness to pay for sites adjacent to the waterways. The actual price attached to these new sites will depend upon local conditions of demand, the price of comparable land in the vicinity, and the cost of dredging and transfer operations in the placement of the fill. All of these factors will vary considerably between projects, but the new sites are clearly a valuable asset for local development.

3. Potential for Greater Beneficial Effects. Dredged material disposal is routinely considered as an operational cost, a disbenefit to navigation if it serves no other useful purpose. However, when its placement is for a useful purpose, as in the case of industrial land creation, then the costs of that placement are subtracted from the increase in land value. If there are no land enhancement benefits involved then the dredging costs are normally substracted from the navigation benefits.

Transportation savings are by far the major benefits attributed to the Greenville project. The land enhancement benefit from the dredged material is less than one percent of the total benefits. However, from the local viewpoint of the Port Authority, the benefits from industrial land enhancement are more important than is indicated by this future. This is evident from the fact that most Port Authorities rank highly the objective of enhancing their local industrial base and its contribution to regional development.

The plan for improving Greenville Harbor consists of widening the existing channel from 250 feet for a distance of approximately 8,000 feet, dredging an inner harbor channel 500 feet wide and approximately 13,300 feet long, and dredging an access channel 300 feet wide into the LaGrange Crevasse area for a distance of 1,500 feet. A fleeting area 150 feet wide and 3,000 feet long would be provided in the first reach of the inner harbor channel. The LaGrange Crevasse area would have a fleeting area 100 feet wide and 1,500 feet long on each side. All channels would have a minimum depth of 12 feet.

Dredged material would be placed adjacent to the channels to provide 280 acres of raised landfill to elevation 152 feet (one foot above the 25-year frequency flow line) and 80 acres at an elevation of 136 feet. Figure VII-A also shows the recommended plan and location of the fill near the existing port area.

Land enhancement benefits from the placement of dredged material were calculated according to Corps guidelines. Increases in land values that result from a navigation project are considered to be either a duplication of navigation benefits or development effects. The only real additional enhancement benefit produced by a navigation improvement is the value of new or filled land created by placement of the dredged material. The Corps calculated the enhancement benefits for the Greenville project as the difference between the present value of the land affected by the project and the value of non-waterfront, flood free industrial land, less development costs.

In order to remove the effect of transportation savings on land value, industrial lands landside of the main line Mississippi River levee were used to determine the estimated market value of flood-free industrial land. The area used to obtain the estimate was the Greenville Industrial Park. This non-waterfront industrial land is developed with paved roads, railroad, water, electricity, and sewage facilities. The market value of these lands was estimated at $10,00 per acre.

Federal agencies such as the Corps must focus their economic analysis on *national interest*. However, it is important to recognize that the use of dredged material for industrial site enhancement has greater benefits than the present net national income approach indicates if the importance of local development considerations are recognized.

(d) Recreational Benefits of Port and Harbor Development

One of the major activities pursued by the Corps in support of commercial navigation is the construction of ports and harbors. This activity often also benefits recreation interests, primarily recreational boaters, but also shore fishing and other shore-based activities. Water quality and traffic conditions in commercial ports, however, generally act as a deterrent to water contact sports such as swimming and water skiing.

The development of ports and harbors offers a protected shelter and supply base from which boaters can venture out on relatively vast expanses of water. For this reason, port and harbor development probably makes its greatest contribution to recreation along the waterways when it occurs on coastal or Great Lakes segments. To look at this relationship in detail, the Upper Great Lakes area (including Lake Michigan and Lake Superior) has been selected as a case study.

1. Description of the Great Lakes. The Great Lakes Basin covers nearly 300,000 square miles, of which about 175,000 are in the United States and the remainder in Canada. The United States portion is made up of about 115,000 square miles of land area and 60,000 square miles of water surface. All of Lake Michigan and about two-thirds of Lake Superior are in the United States portion of the Basin.

The Basin is one of the more densely populated parts of the country, containing approximately 15% of the United States population. There are many large urban concentrations in the Basin, reflecting its high degree of industrial productivity, which is to a large extent dependent on its waterway links to sources of raw materials and world markets for export products. Petroleum refining and steel production, as well as chemical and food processing industries, are concentrated in this area. As a result, the urban population has a relatively high average disposable income and creates a high demand for recreation facilities.

The lakes themselves are very large. Lake Superior (total surface 31,700 square miles, of which 20,600 are in United States waters) and Lake Michigan (total surface 22,300 square miles entirely within the United States) together account for more than half of the water surface in the Great Lakes Basin. The Lakes are fed by groundwater sources, surface runoff, and precipitation. Those lakes surrounded by heavy urban concentrations have recently experienced serious water quality problems due mainly to industrial and municipal waste discharges into the lakes and tributary streams. This applies particularly to Lake Michigan (southern portion), Lake Erie and Lake Ontario.

The Great Lakes sustain high levels of commercial traffic, on the order of 80 million tons annually on Lake

Superior, and up to 130 million tons on Lake Michigan. These shipments are projected to increase sharply on Lake Superior, to around 135 million tons by the year 2000, and somewhat more slowly on Lake Michigan, to around 150 million tons by the year 2000. The principal commodities shipped on the Great Lakes are iron ore, coal, limestone, and grain. Iron ore is the principal generator of traffic on Lake Superior, while most of the traffic on Lake Michigan consists of general overseas cargo. Some of this traffic connects through the Port of Chicago to the Illinois Waterway and thence to the inland waterway system based on the Mississippi River.

Recreational boating is significant on the Great Lakes, with a total of 37 small craft harbors on Lake Superior and 96 on Lake Michigan. Nevertheless, boating is limited by a shortage of access facilities in the more densely populated areas, by the distance between safe harbors, and by wind and wave conditions on the lakes. Sudden storms are frequent and create a serious hazard to small craft. Consequently, the water surface area effectively available to recreational boaters is limited to that within a safe distance of a sheltered port. This area is inadequate to satisfy demand in the southern part of Lake Michigan, resulting in many users trailering their craft for long distances in order to find suitable water space for their planned recreation.

Fishing is also important on the Great Lakes, although it accounts for only 5% (on Lake Superior) to 10% (on Lake Michigan) of all the fishing activity that takes place in the Basin. Commercial fishing, once an important water use, has declined to the point where it is now considered mainly as an extension of sport fishing. In addition to fishing from boats, docks, breakwaters, and bridges also provide opportunities for lakeside shore fishing in urban areas. There is, however, a shortage of public access to fishing sites in the Lower Michigan Basin.

The NWS Inventory identifies 20 commercial ports, out of a total of 44 Corps-assigned ports on Lake Michigan, that provide recreational facilities such as marinas or launching ramps. Other commercial ports are under study for recreational development, and some ports have been developed primarily for recreational use. On Lake Superior, only five commercial ports are reported as having recreational facilities out of a total of 24 ports assigned to the Corps; most of the rest are harbors for recreational craft only.

The Level 1 Framework Study recently completed for the Great Lakes Basin made the following recommendations for federal action in the area of recreation:

(a) Give high priority to development of land-based, water-oriented outdoor recreation facilities in and near large urban concentrations.

(b) Encourage additional public access to private land for recreational purposes, especially in the southern half of the Basin, through incentive programs, education of users and private landowners, and other methods.

(c) Provide recreational boating harbors and harbors of refuge where determined necessary and agreed to in the Great Lakes.

(d) Encourage development of public facilities for recreation by demonstrating the potential for recreation and fishing.

Corps program have responded to these initiatives by enlarging the scope of commercial port projects to include shore-based and water-based recreation opportunities, by providing public access points for fishing and sightseeing, by constructing small boat harbors to provide access and refuge to recreational boaters, and by undertaking a diked disposal program to improve water quality in areas where harbor maintenance requirements produce large volumes of polluted dredged material.

2. Relation of Recreation Benefits to Commercial Navigation. The use of the Great Lakes as a recreational resource is comparatively recent development. A survey of recreational boating in the Chicago District portion (western side) of Lake Michigan in 1971 included an inventory of small craft harbor facilities, including slips, mooring spaces, dry storage spaces, and launching lanes. This made it possible to relate boating use patterns to the availability of harbor facilities. The study also showed that many owners of small boats prefer not to use the Great Lakes for reasons of safety having to do with wind and wave factors, not conflicts with commercial navigation.

The study assumed that boats capable of being launched from trailers would remain in the general vicinity of the launching area. Of the 28 federal ports included in the study, only five had no launching facilities for recreational craft: Pensaukee and Washington Harbors, small recreational ports in Wisconsin; Chicago, Illinois; Gary, Indiana; and Burns Harbor, Indiana. It was found that 35% of trips made by the permanently based boats involved travel between two or more Great Lakes harbors.

The study attempted to estimate benefits to recreational boaters of constructing or improving port facilities to provide shelter and services to transient boats. The study found a peak season on the west side of Lake Michigan, from Waukegan to Two Rivers. It also concluded that savings in boat damages alone would probably be insufficient to justify the construction of new harbors of refuge, and that damages did not seem to vary with the degree of protection provided in existing harbors.

Since the Lake Michigan Regional Boating Survey, plans have been advanced to develop additional facilities for recreational craft in the harbors identified as deficit areas and in other harbors along the Wisconsin coast of Lake Michigan which might serve as harbors of refuge. Using the feasibility study for Manitowoc as an example, it would seem that one purpose of this program is to provide a better separation of recreation from commercial uses of the existing port facilities, thus meeting latent demand for recreation facilities, presumably currently constrained by port congestion and inadequate access. These plans also take advantage of the potential shelter afforded by structures built for other purposes, in this case, a diked dredge disposal area.

A further example of the complementarity between commercial port authority and recreational use in urban areas is found in the integrated development of the Duluth-Superior harbor and waterfront area carried out by the St. Paul District of the Corps. Studies initially focusing on water supply and storm drainage were expanded to include problems of wastewater management and sludge disposal as well as the possibility of constructing recreational boat harbors in the adjoining area of Ashland-Bayfield-Washburn in Wisconsin. This area, on the south shore of Lake Superior, had previously been identified as severly lacking in harbors of refuge for small craft.

Protection is afforded to small boats in the Duluth-Superior Harbor by the natural and man-made features of the harbor design. The quality of the recreational experience, both water-based shore-based, is enhanced by a variety of water quality control measures, including the only diked disposal area on Lake Superior. Opportunities for recreational fishing are afforded both to those who use boats and those who prefer to fish from the shore, from docks, or from breakwaters.

The St. Paul District has also constructed and now operates a Marine Museum as part of the Duluth Ship Canal and Harbor Park waterfront recreational development. This building, located next to the aerial lift bridge, which spans the canal and harbor entrance, provides a historical overview of the growth of Great Lakes shipping. Designed to resemble the bridge of a ship, the museum also offers a fine vantage point for views of the commercial harbor. The part and waterfront development in which the Corps has participated provides many opportunities for shore-based recreation, largely enhanced by the proximity of commercial navigation activity.

3. Potential for Greater Beneficial Effects. Commerciali port and harbor development can be combined with an effort to increase recreation opportunities in urban areas located near a waterway. Commercial ports may serve recreational craft by providing launching areas and storage space, sanitary and supply facilities, and safe harbor in a storm. They also provide convenient points for recreational boaters to gain access to pertinent information concerning navigation conditions and potential hazards. Finally, commercial ports located at covenient intervals make it possible for recreational craft to engage in longer voyages than would otherwise be the case, thus assuring effective access for boaters to more of the nation's waterway system.

Within ports and harbors, these benefits seem to be enhanced by a nominal separation of uses designed to minimize congestion and conflicts. Water quality factors are important determinants of the extent to which a commercial port facility can be used for recreationali purposes. The diked dredged material disposal program seems to offer a promising opportunity to combine water quality control and construction of small boat shelter areas or other recreational facilities.

Land access, traffic patterns and parking facilities are also essential factors to be taken into account in planning for the recreational development of a waterfront area.

The United States Fish and Wildlife has urged that all breakwater construction provide for fisherman access and safety. Recent port development plans reflect Corps compliance with this request. While provision for shore-based fishing is not often made explicit, waterfront facilities are often extensively used for this purpose.

Many major and some minor commercial ports are also points of historic and cultural significance. The Corps could do more to enhance the recreational value of these resources by providing signs and visitor information centers as well as, perhaps, additional marine museums. This activity would generate public relations benefits for the Corps as well, as it could not help but highlight the historical significance of Corps participation in the development of the nation's waterway system.

(e) Socioeconomic Benefits of Integrated Basin Development

The integrated development of a river basin has been found to have far-reaching effects beyond the introduction of a navigation system to a region. The McClellan-Kerr Arkansas River Navigation Project brought water transportation to a semi-arid area which previously was far removed from navigation facilities. The socioeconomic impacts on certain counties in Oklahoma and Arkansas have been significant, although they vary between counties. Specific impacts have been identified in regional economic development, migration and employment, environmental enhancement, fish and game habitats, and recreation. The overall quality of life index is considered to be markedly improved. All of these beneficial impacts are supplementary to the authorized project purposes of navigation, flood control, and hydropower production.

A number of studies concerning the above-mentioned impacts on the Arkansas River have been completed or are presently underway. The Corps Institute of Water Resources has been given the task of analyzing the impacts

of the Arkansas River project. The following section is a resume of the IWR findings to date.

1. Impacts of the McClellan-Kerr Waterway. First, the project appears to have provided a positive environmental enhancement, which has increased the relative social and economic attractiveness of the region. The river system, which historically maintained an erratic and low level of habitat and water quality, has been enhanced in both these characteristics. Water quality has been enhanced in both these characteristics. Water quality was primarily improved by sharp reductions in suspended sediment. Fish and wildlife habitat were principally improved by bank stabilization works and oxbow cutoffs as described above. As a result of the improvement inhabitat and an effective stocking program managed by the state, fishing has improved remarkably.

As a result of these changes, visitation at public use areas on the navigation channel exceeded 14 million user-days in 1978. If the three upstream lakes authorized as part of the original navigation project are added, public use increased to over 27 million user-days in 1978. Surveys of the expenditures of recreational users in 1975 indicated that about $160 million is spent annually on recreation goods and services within the Tulsa, Ft. Smith and Little Rock economic regions. Also, more than 5,800 seasonal and permanent recreation homes were recorded, and recreation equipment investment of over 427 million was estimated.

Environmental quality is now a major national and regional concern. It directly affects economic development since quality of life has become a major factor in industrial location decisions. Although this project originally was justified basically by returns on flood control, navigation and power generation, environmental quality and recreation now appear to be equally significant as incentives for ecnomic development.

Demographic trends show an abrupt reversal in the historic outmigration trends which began in Oklahoma and Arkansas during the 1930s. Population in the 28 waterway counties increased by over 300,000 between 1960 and 1976 to a total of just under 1.6 million. This 24% increase includes about 80,000 net immigration, although ten counties experienced net outmigration in the 1970s. The

counties now experiencing net outmigration are predominantly in the Delta region of Arkansas which has experienced few of the effects of the project. A study of population change by the University of Missouri shows that migrants perceived jobs and recreation as important benefits of the water project. About 25,000 of the immigrants were attracted primarily by the economic development and amenities generated by the project.

The sharp pace of regional industrial development, which traces back to vigorous state efforts begun in the 1950s, has been accelerated. Employment increases totaled 20% in the 1960s and 24.5% from 1970 to 1976. Manufacturing reflected a 55% increase over 1960 and non-manufacturing jobs increased 52% over 1960. While these increases are due to many factors, their timing appears to indicate a linkage with waterway development.

The ways in which various waterway communities have chosen to fashion economic development strategies with waterway links are quite different. Tulsa and Pine Bluff have mounted the most vigorous strategies for port-related industrial development. Other communities have chosen, for a number of reasons, different strategies. In port-related industrial development, the role of the state government agencies has been much smaller than that of individual communities which work primarily with the EDA to fund development.

A survey of manufacturing firms which have located or expanded in waterway counties is presently underway. Preliminary data show that over 468 firms, employing in excess of 59,000 persons, have relocated or expanded since 1970. Food processing, furniture, fabricated metals, machinery and electrical and electronic manufacturers account for over 32,000 employees, which shows that much of the expansion is not within the region's traditional low wage industries. Expansion is occurring in all size firms, and well over 60% of the firms employ 100 or fewer employees, which shows that small companies are benefitting as well as large ones.

2. Potential to Enhance Beneficial Effects. It must be recognized that the McClellan-Kerr Project is a very special case. The potential for inducing socioeconomic change through river basin development has been studied in many parts of the United States, and study recommendations have been implemented in other cases with

less resounding success. Preconditions for the outcomes experienced in the Arkansas River case seem to include: (1) a sparsely populated area subject to outmigration and a lack of economic opportunities prior to the project; (2) a sluggish and sediment-laden river whose quality would be greatly improved by increasing low flows and depth; (3) major prior or concurrent investments in port development, processing industries, and water pollution control facilities; and (4) a national or regional population responsive to change in the environmental quality of different areas. In short, there must exist a transport and water quality constraint on area economic development in order for a project such as this to have a major socioeconomic impact on the region.

The research conducted to date has not clarified the interrelationships of all project benefits and the extent to which industrial deveopment has depended, not only on the availability of cheap power. Further analysis of this issue is needed before it will be possible to determine if a successful project on a regional scale must necessarily include all these features.

There is also a need to distinguish between the types of growth induced by a navigation improvement _per se_, and those induced by an improvement in water quality with consequent environmental and recreational benefits. This is particularly important in the light of the requirements for supplementary investment. The McClellan-Kerr project certainly merits the research effort which has already been expanded and could prove rewarding for additional study which would focus more closely on the cause-and-effect relationship between specific project design factors and specific project outcomes.

(f) Conclusions

The foregoing disusssion of findings and case studies has led to the following conclusions regarding the circumstances under which beneficial impacts can be expected.

1. The beneficial impacts of commercial navigation projects are both planned and unplanned. Multipurpose projects necessarily entail beneficial impacts. These impacts can be enhanced by careful planning and

flexibility in implementation to allow for changing use patterns reflecting the changing composition, needs and priorities of user groups.

2. Beneficial effects can be enhanced by taking potential impacts and the interactions between them into account early in the planning process. Indirect effects can thus be anticipated and turned to advantage. An analysis of these secondary impacts may suggest the inclusion of further mitigating or beneficial measures in the project design.

3. Commercial navigation projects automatically benefit recreational boaters. The maintenance of a fixed depth, the provision of locks, and the regulation of flow on rivers provides security and ease of access to boaters. The magnitude of this beneficial impact varies considerably depending on the type of boat under consideration. Large cruisers and houseboats benefit most from locks, for example, while sailboats benefit from channel maintenance and canoeists from flow regulation. Ports and harbors provide security and services to recreational boaters on coastal and lake segments.

Other beneficial impacts on recreation are achieved through water quality control, regulation of flow, provision of shoe access, and separation of uses. Water quality is a key factor affecting the availability of a water resource for swimming, water skiing, and other water-contact sports. Safety is also assured in these activities by the regulation of river flow. Shore access is a major benefit arising out of Corps navigation activities, especially in urban areas. Both recreational and commercial uses of a waterway are facilitated by a planned separation of these uses.

5. Beneficial impacts on fish and wildlife are due primarily to induced changes in water quality, flow patterns, and other habitat characteristics. Channel alignment projects have the potential for concentrating flows in the main channel and creating new ecological settings in the cut-off "oxbow" lakes. When flows are decreased to the point where a river drops much of its sediment load, water quality and, thus, the environment for fish and wildlife are much enhanced. Such projects may also decrease bank erosion and siltation rates in the vicinity of the oxbow lakes.

6. Disposal of dredged material offers an opportunity to create new land formations. The appropriate use of such land depends primarily on the characteristics and location of the dredged material. Sand and clean sediments can be used to create or replenish beaches or to develop new recreational sites in rural areas. Harbor and turning basin sediments can be used to create industrial sites in urban areas.

7. The diked dredged material disposal program generates structures which may be used as protection for small craft in adjoining waters or as access points for fishermen. New land created by such programs offers a potential for commercial, industrial, or recreational development or some combination of these. Participation by the Corps in urban and regional planning groups will provide an opportunity to maximize the beneficial impacts of this program.

8. Docks, levees, dams and breakwaters also provide access for shore fishing. This beneficial impact can be enhanced by giving consideration to fishermen access and safety features at the design stage. Other shore-based recreational uses, such as picnicking, sightseeing, and strolling along the waterfront, can be taken into account in the design of shore facilities, at very little added expense in most cases.

9. Many waterways give access to historic and cultural features whose use could be enhanced by Corps participation in planning for their development. Tie-up points, access trails, signs, and visitor information kiosks would make it possible for waterway users to appreciate and enjoy these features. An added advantage to such a program is the opportunity it would afford the Corps to publicize its own historic role and cultural contribution to the nation's development.

10. The combination of water quality improvement and increased accessibility is a powerful force for socioeconomic development in a declining area. However, the interaction between the different factors involved in this beneficial effect is still not well understood. There is a need for further research focusing on the linkages between specific project design features and specific socioeconomic consequences.

VIII - POSSIBLE ACTIONS AND RECOMMENDATIONS FOR FURTHER INVESTIGATION

This section of the report summarizes the possible actions that could be taken to improve the waterways and their effects on other water uses. Most of these actions have been noted in the preceding sections with reference to specific case studies and uses, but it was considered useful to treat them together in this section. In addition, this section refers to the principal data deficiencies identified above and recommends further investigation where appropriate.

POSSIBLE ACTIONS

The possible actions or strategies to improve the national waterway system have been classified as follows:

1. Actions to increase lock capacity.
2. Actions to improve or maintain channel dimensions.
3. Actions to improve navigation conditions.
4. Actions to extend the navigation season.
5. Actions to reduce the environmental impact of dredge disposal.
6. Actions to support national defense.
7. Actions to react to national emergencies.
8. Actions to improve waterways safety.
9. Actions to reduce hazardous materials effects.
10. Actions to reduce lock and dam vulnerability.
11. Actions to increase shipper commitment to waterways use.

These categories include collections of individual actions or policies that might be implemented by the Corps of Engineers, or other government bodies with control over a part

of the United States Waterway System or over the effects of its operation or management.

The following paragraphs provide an explanation of each of the possible actions considered by the NWS and their potential effects on water consumption, instream use, recreation, and salt water intrusion. These effects are summarized in Table VIII-1. Where no effect is anticipated the space is left blank.

(a) Actions to Increase Lock Capacity

1. Non-Structural Actions. Non-structural measures, (such as switch boats, up and down policy, capacity rationing schemes, control systems EDP tow handling gear, or use of intermodal transportation to bypass constraint points) are designed to decrease delays in passing commercial traffic through the locks or to reduce safety hazards. Generally, such measures have no effect on water uses other than recreational boating. Locks with congestion problems have instituted, in some cases, and have considered, in many locations, an operating policy which gives a lower priority to recreational boats. Such policies include, a) requiring that recreational boats wait up to three lockages, b) restricting recreational boat passage to certain times, or c) requiring recreational boats to wait until they can be locked through with commercial vessels. With increasing commercial congestion at many locks, it can be expected that there will be increasing pressure in the future to institute locking policies which will be unfavorable to recreational users.

2. Minor Structural Actions. Minor structural actions (such as construction of guidewalls, mooring cells, recreational boat ramps, or approach channels) are designed primarily to increase safety and to facilitate the positioning of tows for lockage. In some instances, such as the Sacramento ship channel, minor structural actions include the provision of ballast discharge tanks to avoid salt water intrusion. Recreational boat ramps and tie-up facilities provide a favorable impact on recreation by reducing recreation craft delay times or fuel consumption while waiting.

Table VIII-1

Strategy Actions and Their Potential Effect On Other Water Users

Strategy Actions	Water Consumption	Effects On: Instream Use	Effects On: Recreation	Salt Water Intrusion
(a) Increase lock capacity				
1. Non structural (switch boats, up and down policy, etc.)			* Scheduling of recreational lockage (+ or -)	
2. Minor structural (guide walls, mooring cells, recreational boat ramps, etc.)			Boat ramps	
3. Major structural (recreational locks, double chambers, lock expansion)		Slight impact from lock expansion as lockage water requirements are small	* Recreational locks (+)	
(b) Improve Channel Dimensions and Maintenance				
1. Compatability of waterway dimensions	Upstream water users impacted by increased channel dimension which require increased discharge	* Increased channel dimensions equals increased flow requirements	Oxbow cutoffs (+)	Deepening channels cause salt water wedge movement (-)
2. Dredging and river training		* F&W habitat changes (+ or -)	Aesthetic impact F&W and water quality impact	

Table VIII-1 (continued)

Strategy Actions and Their Potential Effect On Other Water Users

Strategy Actions	Effects On: Water Consumption	Instream Use	Recreation	Salt Water Intrusion
(c) Improve Navigation Conditions				
1. Improve reliability of flow regulation	* Irrigation & other water supplies affected by reservoir releases (+ or -)	Hydropower, flood control * F&W habitat (+ or -)	Upstream Reservoir (+ or -) * Activity day impact	* Augment low flow on free flowing river (+)
2. Invert in bridge replacement at key points			* Safety for boating (+)	
3. Adequate standards for channel clearance		Minor impact from dredging	*Marina protection (+)*	
4 Improved navigation aids, communication traffic control technology			* Safety for boating (+)	
(d) Extend Navigation Season				
1. Provide winter lockages (heating, bubblers, coating, etc.)		*Impact on F&W around lock (+ or -)	*Small impact on boating*	
2. Maintain open channel (ice break, ice booms, bubblers)	Impact on all users if increased annual discharge required	* Change in F&W habitat (+ or -)	Animal migration (-), Change in overall recreation use from ice to open water	

Table VIII-1 (continued)

Strategy Actions and Their Potential Effect On Other Water Users

Strategy Actions	Water Consumption	Effects On: Instream Use	Effects On: Recreation	Salt Water Intrusion
(e) Reduce environmental impact of dredge disposal				
1. Develop techniques & & strategies to reduce amount of dredging		* Impact on habitat (+ or -)	Water quality improved	
2. Encourage upgrading of dredge fleet quality				
3. Integrate WES research findings into current disposal practice		* Impact on habitat (+)	Impact on general recreation (+)	
4. Reduce amount of soil runoffs into waterways			Water quality improved (+)	
(f) Support National Defense				
1. Maintain adequate dredge fleet for key ports & for terminals				
(g) React to National Emergencies				
1. Provide standby ability to clear obstructions and damage				

Table VIII-1(continued)

Strategy Actions and Their Potential Effect On Other Water Users

Strategy Actions	Water Consumption	Effects On: Instream Use	Effects On: Recreation	Salt Water Intrusion
2. Clarify lead agency role in emergencies				
3. Provide standby authority to move high priority cargo				
(h) Improve Waterways Safety				
1. Major expenditure needed to reduce hazards (penalties for failure to remove hazards quickly)	Small impact on water quality by reducing accident risk (+)	* Reduce spills (+)		
2. Increase emphasis on safety training and enforcement			Recreational boating (+)	
3. Research better tow, ship, navigation technology				
(i) Reduce Hazardous Material Effects				
1. Better accident response (contigency planning, special task force)	Small impact on water quality from quick clean up (+)	Less damage to aquatic habitats (+)	High impact on recreation (+)	
(j) Reduce Lock & Dam Vulnerability				

Table VIII-1 (continued)

Strategy Actions and Their Potential Effect
On Other Water Users

Strategy Actions	Water Consumption	Effects On: Instream Use	Effects On: Recreation	Salt Water Intrusion
1. Timely rehabilitation program				* Environmental damage from lock failure (+)
2. Better design of locks (application of state of the art)			Recreational boating (+)	
3. Contingency planning (special task force: equipment)		Impact on habitat from lock failure (+)		
(k) Increase Shipper Commitment to Waterway Use				
1. Need long range system plan with appropriate 5 year review to reassure shipper making long term investment		Higher navigation demand and better planning (+ or -)	Better planning (+)	Better planning (+)

* = Significant Consideration
\+ = Positive Impact
\- = Negative Impact

3. Major Structural Actions. Major structural actions (such as construction of new recreation locks and double chambers or lock expansion) include the replacement or addition of lock facilities to meet present and projected traffic volumes. Increasing the size of locks will have a negligible effect on water requirements for lockages and will have little impact on instream water use other than recreation. Many lock expansion actions are designed to permit the passage of larger tows and reduce lockage times, which will relieve congestion around locks and, therefore, aid recreational boating.

The addition of recreation locks or other facilities to pass recreational craft around locks and dams will have a major positive impact on recreation. Recreation locks may promote increased recreation traffic in areas that are presently avoided by recreation craft because of congestion and long waits due to high commercial activity. The impact of the introduction of recreational facilities will be partly dependent on the type of equipment provided.

Several technologies are being considered to pass recreational craft around dams. These include canvas slings or steel tanks to lift the craft from one level to another or an inclined plane with moving locks, such as has been used in Europe. A more complete description of possible technologies for the separate handling of recreational craft is provided in the Element K report. Separation of recreational craft from commercial traffic would not only be of assistance in moving waterborne commerce, but would also provide a safety improvement.

(b) Actions to Improve or Maintain Channel Dimensions

1. Changes in Channel Dimensions or Channel Alignment. Waterway dimensions are dependent upon a number of factors. Authorized channel depths and widths are determined by 1) design flows which are selected from a probability distribution of historic flows for a specific reliability and 2) the projected size and number of commercial craft which will utilize the waterway. The actual channel dimensions on free flowing segments, and to a

lesser extent on channelized waterways, are also dependent on streamflow, sediment load, and dredging. This relationship is not a simple one and varies seasonally as well as anually. On some rivers, such as the Missouri and the Columbia, a high degree of control over river stage is maintained through releases from upstream reservoirs. On others, dredging is the primary means of maintaining channel dimensions.

On some segments, changes in channel dimensions or alignment are under consideration in order to make the segment design more consistent and compatible with the needs of current commercial craft, particularly tows.

Such potential changes include: 1) channel widening, 2) channel deepening, 3) change in the radius of curvature, and 4) changes in channel alignment (construction of cutoffs). Each of these changes has a potential impact due to induced changes in flow requirements to maintain authorized depths.

The major impact on other water uses comes from the increased flow requirements occurring on free-flowing segments. Proposals to deepen and widen channels may require increased flows which could have a negative effect on water availability for upstream uses. Conversely, increased consumptive use upstream could make it more difficult to maintain downstream channel dimensions.

Changes in curvature may have a minor impact on upstream uses if flow requirements are altered as a result. This impact is expected to be minor in magnitude.

The use of cutoffs to improve flow conditions and to provide better channel alignment has been found to be beneficial to fish and wildlife and recreation interests in some cases.

Channel deepening projects in coastal regions have caused salt water to intrude further upstream and this threatens water supplies in some instances. This impact, however, can usually be controlled by mitigation measures and is therefore considered small.

2. Dredging and River Training. Dredging and river training actions are intended to insure authorized channel dimensions by concentrating flow in the desired

channel areas. The frequency and volume of dredging required is dependent upon several factors, including the amount and nature of sediment entering into the river, the shape of the flood hydrograph, and the occurrence of natural river features, such as rock sills and meander patterns. River training structures facilitate channel maintenance by concentrating flows into preferred locations so as to enhance sediment transport, reduce shoaling, and increase channel depth.

Dredging and river training have no effect on water consumption, but may have significant effects on instream uses. Dredging has been found to provide either a positive or negative impact at both the dredge site and the disposal site. Dredging will destroy on-site habitats of bottom dwelling organisms. It also increases turbidity, which may affect aquatic life for some distance away from the actual dredge site. On certain river segments, such as the Lower Mississippi, the river bed is unstable through much of the year and supports few if any benthic organisms. Dredging in such locations has an insignificant effect on changes in habitat.

Dredged material disposal may be accomplished instream, upland, or at ocean sites in the case of coastal and port operations. Disposal at any of the three site types will obviously alter existing habitats, thus providing a negative impact. Dredged material, particularly around ports, is sometimes contaminated with heavy metals or other toxic substances and disposal can only be made at selected locations. The selection of upland sites in particular require special attention to drainage patterns in order that the effluent does not contaminate other water supplies.

Positive impacts from dredged material disposal include the creation of marshlands, beach enrichment, and industrial sites. The use of dredge material to create industrial lands may produce real estate of high market value during port expansion operations. In other cases, dredged material has been used to create new land for recreational and/or environmental protection purposes.

Dredging and river training have other effects on recreation users. The aesthetic impacts of dredging operations are generally negative. Upland dredged material disposal sites are initially barren and unsightly and may have a negative effect on wildlife, although it is

usually short-lived. The longer term effects of dredged material disposal sites can be either positive or negative depending on how the sites are managed.

River training structures may have either negative or positive effects on fish and wildlife habitats, depending upon the previous river conditions. In some cases, notched dikes have been utilized to improve fisheries habitat. A complete analysis of dredging and river training and their effect on aquatic habitats is provided in the Element M report.

(c) Actions to Improve Navigation Conditions

1. Improvement in the Reliability of Flow Regulation. Flow regulation provided by releases either from upstream reservoirs or from instream hydropower projects has been found to affect navigation in several cases. Although there are few reservoirs in the Corps system that have storage allocations specifically set aside for navigation, there are many more reservoirs whose releases for other purposes also provide flows for navigation. The most notable example of navigation being dependent on other reservoir releases is in the Missouri River.

Improving the reliability of flow regulation can be accomplished by obtaining a higher degree of control over storage volumes set aside for navigation by the use of multipurpose storage for navigation or by the construction of more reservoirs. Any changes in present storage allocations can only be made at the expense of some other water user. High consumptive uses, such as irrigation, can be expected to be affected the most under such circumstances.

Instream uses of hydropower and flood control are affected by flow regulation. In many instances hydropower production is most efficient when generation is scheduled on a peaking basis to meet the highest daily and weekly demands. Peaking releases sometimes produce high flow velocities downstream and rapidly fluctuating river levels which inhibit navigation.

The Alabama River provided an example of hydropower releases which, because of their peaking schedules,

cause low flows to occur on the Alabama River. Several strategy measures have been considered to alleviate the problems associated with this situation.

One solution was to set mandatory weekly release volumes with minimum releases established for weekends. A more regulatory approach suggested changing the rule curves of the individual dams. The revised rule curves would require drawdowns during the fall to meet navigation needs. Both of these proposals would probably reduce hydropower production from the Alabama basin projects.

A more flexible approach suggested applying discretionary authority to allow storage of water in the flood pool through raising the height of the power pool. This would be a temporary measure that would only be implemented after consideration of the short-term forecasts and the possibility of flooding. It would provide a benefit to hydropower as well as helping to alleviate the low flow problem downstream. There would be a potential negative impact on flood control through a reduction of the amount of available flood storage space. However, with careful calculation of the short-term probability of flooding, this impact should be small.

It should be noted that in contrast to the Alabama River case, navigation and hydropower production, particularly from run-of-the-river type projects, are generally compatible and produce complementary flow conditions if the peaking schedules are moderated.

Releases for flood control have also been found to be detrimental to navigation in certain instances, as on the Arkansas River. Increased upstream storage of flood flows would allow a more tapered release of water and improve the reliability of flows in the commercial waterway, at the short-term expense of future flood control storage space.

Both hydropower and flood control releases have a significant impact on fish and wildlife habitats. Very high flows or very low flows may be detrimental to fish and wildlife interests.

Recreation interests are affected by reservoir releases which cause rapidly fluctuating pool levels or pools that are drawdown to very low levels. Such pool fluctuations are detrimental to fish habitats, boat ramps

and swimming areas and cause unsightly exposure of the shoreline. This decrease in attractiveness has a significant impact on visitor days, decreases the enjoyment of recreationists who do come, and decreases local income from recreation.

Salt water intrusion is favorably affected by flow augmentation releases. Increased flows on free-flowing segments will limit the advancement upstream of the salt water wedge during the dry season or during droughts. The Deleware River, the San Francisco Delta area, and several selections of the Louisiana coastal zone have all been benefited by upstream flow regulation which influences salt water intrusion.

2. Investment in Bridge Replacement at Key Points. Bridge clearances, both vertically and horizontally, are key elements in providing safe navigation conditions. Factors which affect navigation conditions around bridges include flow velocities, the location of the bridge with respect to channel alignment, the height of the bridge above high water, the visibility of the bridge at night during foul weather conditions, and the volume of traffic. In some locations moveable span bridges are necessary to allow passage of tall vessels, both commercial and recreational.

Bridges are a factor in recreational boat safety as well. Whenever an obstacle to commercial navigation is removed, it will benefit recreational boating as well, particularly larger craft.

3. Establishment of Adequate Standards for Channel Clearance. This action has no effect on other uses unless flow regulation or structural changes in channel dimensions are involved.

4. Installation of Improved Navigation Aids, Communication, or Traffic Control Technology. Improved navigation aids may have a significant positive impact on recreational boaters. Increased communication will allow boaters to plan their lock arrival times to best suit their needs. Increased traffic control, including speed limits and physical separation of different types of traffic, should also aid both commercial and recreational vessels avoid accidents.

(d) Actions to Extend the Navigation Season

1. Provision of Winter Lockages (i.e. using heating, bubblers, coating, etc.). In the nothern regions of the waterway system ice conditions disrupt and at times prohibit navigation during the winter months. Ice conditions at locks and dams are particularly troublesome because of the buildup of ice in these narrow passages. Efforts to extend the navigation season by combating ice conditions at locks include heating, bubblers, and coatings to reduce ice adhesion on lock walls, gates, and gate reccesses.

Raising the water temperatures, providing open water, and allowing boat traffic will have an effect on the microenvironments around the locks. This effect could be either positive or negative depending on the species of aquatic organisms at the site. However, because of the limited areas of the locks any possible impact will be minor. The recreational impact is also minor as recreation demand is very low in winter months.

2. Open Channel Maintenance (i.e., using ice breaking, ice booms, bubblers). Providing year round open channels where ice conditions normally prevail will have an effect on the local water environment. These effects include impacts on the physical environment, such as decreased water quality; resuspension and redistribution of bottom sediments; increased turbidity; alteration of existing water levels, flows, and current patterns; shore vibrations caused by vessel movement through ice; and ice movement causing disruption of shoreline, littoral zone, and wetland vegetation. Possible impacts on the biological environment include: disruption of fish and wildlife habitats; changes to fish and wildlife behavior patterns (i.e., fish spawning, fish and wildlife migration, etc.); and alteration of fish and wildlife population densities. These impacts can be either positive or negative depending on the environmental effects.

There is a potential effect on consumptive users of water upstream if the maintenance of open channels during the winter months requires the utilization of storage volumes which otherwise would be made available for other consumptive uses, such as irrigation.

(e) Actions to Reduce the Environmental Impacts of Dredge Disposal

1. Reduction in the Amount of Dredging Required. Strategies to reduce the amount of dredging necessary to maintain channel dimensions have been attempted on a trial basis at several locations. The most notable example has been on the Upper Mississippi as part of the GREAT studies. Although there has been a reported increase in the number of groundings on the Upper Mississippi, it is not yet clear if this is due to decreased dredging or to lower than normal flows in recent years.

Attempts to dredge in advance of the flood season have been successful in some cases and unsuccessful in others. Some rivers have particular trouble spots that require annual dredging, while other river segments may develop shoals on a totally unpredictable basis. This lack of precision has led to the belief that the determination of dredging requirements is to a certain extent an art that can be successfully practiced only after years of experience and observation.

Reducing the amount of dredging on a waterway segment may lessen the negative effect on fish and wildlife habitats which occur from dredging. Water quality can be expected to be improved to a degree because of reduced turbidities which will occur in proportion to reduced dredging. Impacts on fishing and recreation come indirectly from the impacts on water quality and dredge material disposal.

2. Encourage Upgrading Dredge Fleet Quality. Technical advances are being made in the design of dredging equipment that bear on the efficiency and cost of dredging. Operations in some waterways are presently dependent upon older equipment or types of equipment that limit the choices of dredge disposal sites. Upgrading of the dredge fleet would permit a wider choice of dredge disposal sites, with possible positive impacts on recreational, commercial industrial, or environmental land uses.

3. Changes in the Criteria for Selecting Dredged Material Disposal Sites. Disposal practices are currently dictated by a variety of considerations, including the

type of dredge equipment available distance and cost of transporting the material, local environmental concerns and regulations, and the availability of local sponsors. Integrating WES research findings into current practice will involve site specific considerations including all of the above mentioned items. One of the most significant proposals, in regard to its impact on other water users, is the proposal to increase the beneficial uses of dredged material, such as the use of dredged material to improve recreational fish and wildlife sites alluded to earlier in this report. The creation of marshland habitats and beach enrichment are significant benefits for which dredged material can be utilized in many cases.

4. Reduction in Soil Runoff into the Waterways. The majority of sediment introduced into the waterways is derived from tributary streams and rivers during the flood season. The availability of sediment in the tributaries is primarily a function of land use activities which reduce natural vegetative cover. Cultivation of farm lands and to a lesser extent urbanization are the primary instigators of erosion and subsequent sediment availability. Soil erosion control is outside the domain of Corps, but other federal and state agencies have active programs for reducing soil erosion.

On some waterway segments bank erosion is a problem because of wave wash from deep draft or rapidly moving vessels. Techniques which have been utilized to reduce bank erosion include revetments on banks and the setting of limits on vessel speeds.

A reduction in sediment introduced into the waterways will be beneficial in terms of water quality and will therefore aid fish and wildlife and recreation interests. However, if land use for agriculture or recreation is constrained, this may have a negative impact. All these potential impacts, however, are relatively small.

(f) Actions to Support National Defense

Maintain Adequate Dredge Fleet for Key Ports and Terminals. The maintenance of such a dredge fleet will have no apparent impact on other waterway users.

(g) Actions to React to National Emergencies

1. Provide Standby Ability to Clear Obstructions and Damage. Such a standby ability of equipment will have no apparent impact on other waterway users.

2. Clarify Lead Agency Role in Emergencies. At present there are at least three agencies with waterway-related responsibilities in the event of a national emergency. Clarification of the relationship among these agencies and initial cooperative contigency planning is needed. Such actions will benefit other waterway users to the extent that they may become informed of possible agency actions in the case of an emergency and incorporate these contingencies in their own forward planning.

3. Provide Standby Authority to Move High Priority Cargo (e.g., an energy mobilization board). There is no apparent effect of this on the other waterway users.

(h) Actions to Improve Waterways Safety

1. Reduction or Removal of Hazards. Accidents which produce residual hazards to the operation of the waterways require prompt and timely attention. Sunken craft create an obvious physical barrier to the waterways that can endanger or impede both commercial and recreational craft. Accidents which produce spiils of chemicals or petroleum products are particularly detrimental to fish and wildlife habitats and recreation users. Consumptive use such as municipal and irrigation water supplies may also be affected by spills.

There are a number of possible actions considered under this sub-heading. One is for the Corps to constitute a special task force with specialized equipment to deal promptly with wrecks or spills. Another is to provide stiffer penalties for delays in action by private parties responsible for hazard removal. Any actions taken to preserve or enhance water quality will benefit fish and wildlife as well as recreation and consumptive uses.

2. Increased Emphasis on Safety Training and Enforcement. Training and informing waterway users and enforcing waterway regulations are important aspects of waterway safety. The Coast Guard carries major responsibilities in these areas. Enforcement of waterway regulations, particularly in regard to vessel speed, has been identified as troublesome to both commercial boat operators and recreation interests such as marinas. Commercial operators are normally interested in navigation at speeds as close to the maximum as possible. On some waterways high vessel speeds have been found to produce waves that erode banks and interfere with other vessels both moving and moored. The strict enforcement of waterway regulations provides a safety benefit to recreational boaters. Similarly, increased emphasis on safety training and enforcement of regulations applying to recreational boaters will benefit both the safety of recreational boaters and the efficiency of commercial operations.

3. Research Better Tow, Ship, Navigation Technology (*i.e.*, to implement NTSB recommendations). The NTSB recommendations on navigation technology are considered to have no significant effect on other waterway users.

(i) Actions to Reduce Hazardous Material Effects

1. Improved Accident Response (*e.g.*, contingency planning, special task force). The transportation of hazardous materials and their potential entrance into the waterways because of accidents is a continuing concern. Increased efficiency in response to accidents is needed in order to reduce the spread of hazardous substances and facilitate a quick and thorough clean-up. Contingency planning to identify the hazardous materials, to describe their handling and containment, and to determine the suitability of specific waterways for their transportation will reduce the possibility of damages from spills.

Actions to improve response procedures in the event of spills will have a positive effect on downstream consumptive, instream, and recreational users. All of these water users will incur less potential damage if hazardous spills are reduced.

(j) Actions to Reduce Lock and Dam Vulnerability

1. Timely Rehabilitation Program. A continued rehabilitation program of locks and dams should be an integral part of an efficient waterway operation. Lock failures because of neglected maintenance could result in long delays and disruption of waterway network transportation.

Failures of salt water barrier locks at key locations could allow the intrusion of saline waters into fresh water zones. Long term damages to irrigation and fish and wildlife habitats would be a consequence of such lock failures. The proper rehabilitation of salt water barrier locks is therefore considered a significant action in order to avoid future problems of salt water intrusion. Water supplies from pools may also be more reliable due to this action.

2. Better Design. Many of the locks and dams on the waterway system presently are and would further benefit from an application of state-of-the-art design. Locks which are presently bottlenecks in the waterway system have been identified in Task K1-008.

Improved lock design would be of benefit to recreational boaters where congestion would be reduced.

3. Contingency Planning. Contingency planning for lock and dam failure (such as special task force; or special equipment) is a precautionary measure that will potentially reduce damages should such an event occur. Reducing the risks of lock and dam failure will help avoid damage in natural habitats and thus provide a positive benefit to fish and wildlife interests, as well as to recreational boaters.

(k) Actions to Increase Shipper Commitment to Waterway Use

1. Provide Long-range System Plan. With appropriate periodic review to reassure shippers making long-term investment commitments to water transportation.

Increasing shipper confidence in the long term operation of the waterways will require long term planning with appropriate Corps commitments to the efficient operation of the waterways. Long range planning which views the waterways as a multipurpose system will also provide a framework for the integration of uses which will afford benefits to all multipurpose users. Better planning for instream users, recreation, and the prevention of salt water intrusion will also allow these users to plan their investments for the most efficient use of water resources.

(1) Proposed Actions by NWS Segment

The Element K report provides an analysis on a segment basis of actions that have been evaluated in the past by the Corps as options to channel maintenance programs with the ultimate objective of improving navigation conditions. A summary of the potential actions is presented in Table VIII-2. This table also contains an assesment of the effect on river flow of the potential action and the potential water users affected.

Under the column "Effect on Flow Requirements," an estimate is made of the degree of increase or decrease in flow that the proposed action would be likely to cause. These estimates should be considered as orders of magnitude only, as the actual effect on the flow regime of a river is complex and can only be accurately predicted on a site-specific basis. In the case of increasing channel depths and widths a percentage value of effect on flow is provided. The percentages relate to the proposed increase in cross-sectional area of the navigational channel, although the actual increase in flow required to provide these dimensions may be considerably less. It is further conceivable that larger rivers, of which only a relatively small percentage of the cross-sectional area is allocated to navigation, would not require any increase in discharge as a result of increases in channel depth and perhaps could even lower the flow requirements. Again, the actual flow requirements can only be assessed on a site-specific basis.

The column headed, "Potential Water User Affected," is subdivided into "Consumptive" user, "Instream" or non-consumptive users, and a separate category for "recreation."

Table VIII-2

NWS Segments and Potential Actions

Segment	Potential Action	Effect on Flow Requirements	Potential Water User Affected: Consumptive	Instream	Recreation	Salt Water Intrusion
1. Upper Mississippi (Segment 1)	Additional locks	None			Boating (-)	
	Reduced dredging volumes	Increase				
	Construct recreation locks				Boating (+)	
2. Lower Upper and Middle Mississippi (Segments 2 & 3)	Deepen channel - 9' to 16'	Large increase Industrial (80% in cross-section area)	*Irrigation* (-)		Boating (+)	
	Improve reliability of 9x300 channel	Small increase	Irrigation (-) Industrial (-)			
3. Lower Middle & Lower Mississippi (Segments 4-6)	Deepen channel - 9' to 12' to 16' (Cairo to Baton Rouge)	Small increase (25-80% in channel cross section area in high flow segments)	Irrigation (-) Industrial (-)		Boating (+)	Municipal
	Deepen and widen channel 12x300 to 40x500 (Natchez to Baton Rouge)	Very large 300% in cross-section area	Irrigation (-) Industrial (-)		Boating (+)	Municipal
4. Illinois (Segment 9)	Larger locks with 12' sill	Slight increase				
	Increase dredging volume	Decrease				
	Recreation lock	Slight decrease			Boating (+)	
5. Missouri (Segment 10)	Training and stabilization structure	Slight decrease			F&W (+ -)	
	Terminate navigation	Large but gradual decrease	Irrigation - large scale (+)	Hydro, (+) Reservoir release	+ or -	

Table VIII-2 (continued)

NWS Segments and Potential Actions

Segment	Potential Action	Effect on Flow Requirements	Potential Water User Affected: Consumptive	Instream	Recreation	Salt Water Intrusion
6. Monogahela, (Segment 17)	No maintenance	None				
	River training	Slight decrease			F&W (+)	
	Alternate dredging procedures	None				
	Recreational locks	None				
7. Allegheny (Segment 17)	No maintenance	None				
	River training	Slight decrease				
	Alternate dredging measures					
	Recreational locks	None			Boating (+)	
8. Cumberland (Segment 21)	Modified power releases	Unknown, depends on modifications		Hydro		
	Channel improvement	None				
	Stilling basin at Barkley L/D	None				
9. White River (Segment 24)	Deepen channel - 4.5' to 9'	Small increase	Irrigation (-)			
	Channel alignment	None				
10. GIWW LA-T (Segments 28-30)	Deepen channel - 12' to 16'	None			F&W	Irrigate
	Widen channel - 125' to 300'	None				Irrigate F&W
	Channel alignment	None				

Table VIII-2 (continued)

NWS Segments and Potential Actions

Segment	Potential Action	Effect on Flow Requirements	Potential Water User Affected: Consumptive	Instream	Recreation	Salt Water Intrusion
10. GIWW LA-TX	Relocate Colorado River locks	None				
	Bank protection	None				
11. Tenn Tom & Tombigbee	*Completion of Tenn Tom* project	Large increase			F&W (+)	
(Segments 35 & 37)	Channel alignment	None				
	Duplicate locks	None				
12. ACF (Segment 38)	Abandon project	None				
	River training	Slight decrease	Domestic (+) Power Plants (+) Industrial (+) Irrigation (+)			
	Construct lock & dam - Suttons Lake	Increase		Reservoir Release		
13. Great Lakes, Saint Lawrence (Segments 45-49)	Increase channel cross section by increased dredging	Decrease velocity	None			

For those segments that have been identified as having future water shortages, the water user that will be most likely affected is indicated. Consumptive water users that are predicted to be affected by the proposed action are limited to the larger consumers, who take up at least 10% of the total water volume utilized. Only the water uses of irrigation, industrial use, domestic consumption, and power plant cooling were found to be potentially affected. A positive or negative evaluation of the proposed actions' effect on the water user is also provided.

"Salt Water Intrusion" is treated separately, as it involves a determination of water quality rather then quantity. It was found that actions would potentially affect municipal, irrigation, and fish and wildlife waterway users.

DATA DEFICIENCIES AND FURTHER RESEARCH

In the course of the analysis carried out for the NWS analysis of the other water use interactions with navigation, many areas of data deficiencies were discovered with varying degrees of possible influence on the conclusions. The more significant of these are described below by analytic area. Where the influence could be significant, further investigation is recommended.

(a) Water Availability Data

The primary data used in this part of the analysis were from the second National Water Assessment. These data are solid on the supply side, although there is some uncertainty on the forecasts of future water demand, particularly in industrial water supply. The NWA data were adjusted for macroeconomic changes but the unit costs are derived from the NWA analysis. The industrial water demand data, on the other hand, are not as critical as the irrigation water supply data, which account for 80% or more of demand in the western states.

The irrigation demand for surface water is only a fraction of the total demand, but this is critical to the availability analysis for navigation. There is a high uncertainty in these forecasts due to the unknown future shift from ground water to surface water, and the potential transfer of water within the Arkansas, Red and Missouri River Basins.

Additional work is now being carried out for the Missouri, Arkansas, and Red Rivers and this should be continued. Further investigation is recommended in this area for water availability on the Middle Mississippi.

(b) Instream Flow and Reservoir Management

A further uncertainty is the future influence of environmental factors on low flow in those waterways with large upstream consumptive demand. If environmental and fish and wildlife interests establish minimum low flow conditions, these will generally exceed navigation needs. Therefore future environmental requirements for low flows are critical to navigation needs. It is recommended that any requirements of this type be monitored in the future by the Corps.

Where energy demands on water are primarily related to hydropower management of reservoir releases, future peaking use will have a significant impact on the timing of flows. This affects navigation on certain waterways (particularly the Alabama, the Apalachicola, and perhaps the Columbia and the Missouri in the future). The shift to more peaking use of hydropower has been predicted, but not in any detail. This data area is recommended for further investigation as part of the national hydropower study.

Reservoir management of multipurpose systems is now in a relatively simple stage with many decisions based on engineering judgement with little knowledge of actual social or economic consequences. The best multipurpose reservoir management systems on the Missouri, the Arkansas, and the Columbia, still have only rudimentary data and rule curves with which to make major decisions. It is

recommended that the data base for real time trade-offs between uses of the reservoirs (recreation, hydro-power, water supply, and flood control in particular) be further developed to assist in reservoir management decisions for the five critical basins noted above.

(c) Salt Water Intrusion

Recent developments in hydraulic models have greatly improved decision-making and project design in this area with respect to navigation projects. Sensitivity tests may be desirable to supplement the available models. In addition it is recommended that hydraulic models be developed in other areas that are not presently modeled but which have potential salt water intrusion problems.

(d) Recreation-Navigation Interactions

This study area contains many data gaps, since the best data available on the national level, the Corps' RRMS, is very spotty and not completely systematic. This data system requires a major verification and expansion effort in order to provide genuinely reliable data for the NWS analysis. Particularly, more data are required on the effects of reservoir regulation on recreation, and the effects of commercial lockages on recreation lockage demand. Although a general analysis was carried out as part of the NWS, these data represent the weakest part of the analysis and it is recommended that this be investigated further for those segments with locks or reservoirs associated with commercial navigation.

A further data gap is noted in the impact of commercial navigation on marina developments. This relationship is significant on certain segments with many marinas directly adjacent to the channel. These segments, however, make up only a small part of the total waterway syste..

A similar problem is apparent from the port and channel analyses. The conflict between commercial use and recreation use is a perceived one that varies from site to site and from person to person. In general, there is a modus vivendi established between recreation boaters and commercial craft; but the increasing number of these conflict sites leads to a recommendation for further investigation on a site-by-site basis, and a set of planning guidelines to minimize these conflicts.

(e) Beneficial Effects

The beneficial effect of navigation projects are also little-known because they are generally indirect effects on fish and wildlife, recreation, and port or regional development. These effects tend to be very site-specific. However, they are significant and very dependent on project design techniques. Further effort is needed to ensure that the greatest possible beneficial effects are planned into future projects. The Corps has developed some techniques in this area, but it is recommended that these be applied systematically to all projects, and expanded to include all the effects discussed in Sections VI and VII. Further research is recommended to accomplish this objective.

CONCLUSIONS

(a) Possible Actions

1. Consumptive Uses. There are few strategy actions that will have a significant effect on water consumption. The primary action in this respect is reservoir regulation that releases water for navigation purposes which could be used upstream for water supplies or irrigation. Increasing channel dimensions may also require increased discharge on certain waterways. This could lead to reduced water availability for upstream consumptive users such as irrigation and municipal interests. Extending the navigation season is a second action that also requires increased discharges and may affect the utilization of upstream reservoir storage volumes. Downstream consumptive users are favorably affected by actions that reduce the possibility of accidents involving hazardous materials.

2. Instream Users. There are several possible strategy actions which may affect instream uses of the waterways. Increasing the channel dimensions will require additional flows on certain waterways. Such changes could alter flood routing considerations and also impact on run-of-the-river hydrpower installations. The effect of discharge changes could be either positive or negative, depending on site-specific considerations.

Actions to improve flow reliability through regulation have the same effects as those described above. Changes in reservoir release schedules will have varying effects on flood control, hydropower, and fish and wildlife habitats. The use of dredging or river training techniques to improve channel dimensions will also have a significant effect on fish and wildlife habitats. The actual impacts can be either positive or negative but can only be described on a site-specific basis.

Actions to extend the navigation season through the provision of winter lockages and the maintenance of open channels have a potentially significant impact on fish and wildlife interests. Changing ice conditions to open water will have effects on aquatic organisms, although no judgments as to the desirability of such a change are possible except on a site-specific basis.

Actions intended to reduce the environmental impact of dredged material disposal should have a positive effect on fish and wildlife habitats and recreation sites. These actions include the development of techniques to reduce the necessity of large dredging volumes and the increased use of dredged material for beneficial purposes. Identical beneficial purposes include the creation of industrial sites through land fill, the creation of marshlands for wildlife habitats, and beach enrichment.

Actions to improve waterway safety and to reduce the effects from spills of hazardous materials will have a positive effect on water quality. This will in turn reduce the incidence of damage to aquatic habitats.

Increasing shipper commitments to the waterways through long-range planning should allow all waterway users an increased degree of confidence in planning their respective activities. Greater reliability of waterway management, the identification of future needs, and the adoption

of commitments will permit a higher efficiency in multipurpose use of the waterways.

3. Recreation. Non-structural actions to increase lock capacity include the scheduling of recreational lockages. At some locks the quality of recreation is reduced because of long delays in locking through. Major structural changes in locks may include the provisions of separate facilities for recreational craft. These may include separate locks or facilities such as a "sling" to lift the craft over the dam to the opposite side. These actions would have a significant positive effect on recreation.

Dredging and river training have impacts on fish and wildlife which have been described earlier in the "Instream Use" section. The water quality and aesthetic implications of dredging have particular importance to recreation interests.

Actions to improve navigation conditions through reservoir regulation have significant impacts on recreation both in the reservoir pool and downstream. Extreme high or extreme low pool levels have a direct bearing on user satisfaction. There may be only a narrow of pool stage or river flow conditions that are conducive to good recreation. Boating safety provided by adequate clearance around bridges and marinas, improved navigation aids, and better traffic control technology are all important actions for recreation interests.

Actions to reduce environmental impact by reducing the amount of sediment discharge into the waterways could have a significant positive effect on recreation. Turbidity is a factor in water quality and thus directly affects the suitability of a waterway segment for recreational use.

Actions to increase shipper commitment to the water-ways will promote increased commercial use of the waterways, possibly competing with recreational traffic. Improved long-range planning for the benefit of all waterway users should mitigate this impact and lead to more efficient use of the waterways for recreation as well.

4. Salt Water Intrusion. The list of strategy actions contains few items that directly affect the problem

of salt water intrusion. Those actions considered significant include channel deepening to increase waterway dimensions, flow regulation to improve navigation conditions, rehabilitation of locks to reduce their vulnerability to failure, and better long range planning.

Channel deepening and/or reduction of flow may facilitate the movement of saline water into undesirable areas. Irrigation, municipal water supply, and fish and wildlife habitats are all sensitive to water salinity and must be protected.

Salt water barrier locks require particular attention to maintenance in order to avoid failures and resulting salt water intrusion into fresh water zones. Significant environmental damage could result along certain water-ways should these barriers fail.

Finally, improved long-range planning is expected to provide water users with better assurances concerning the future of water quality along coastal segments. Mitigation measures to reduce damages produced by projects which may create salt water intrusion problems should be included in the planning efforts.

5. Summary of Impacts. The pattern that emerges from the above discussion of impacts is that the major link between Corps actions and other water users comes through their effects on flow and related reservoir regulation. All of the impacts on consumptive uses, part of the recreation and part of the fish and wildlife impacts are tied to these two physical aspects of the waterway system.

Recreational boating is clearly affected by the existence of locks and their operating procedures. In addition, there are minor safety impacts of other Corps actions. Recreation is also affected negatively by dredging and positively by creation of fish and wildlife habitats through dredged material disposal, oxbow cutoffs, or other actions.

The interactions of other water uses and their potential linkage to scenario assumptions and strategy actions in the NWS analysis are depicted in Figures VIII-A and B. These figures show the major interactions resulting from reservoir actions, lock and dam actions, and dredging actions.

(b) Recommendations for Further Investigation

Further research is recommended in each area of the above analysis where data are weakest. However, the available data appear sufficient for national-level analysis in its present form. More detailed investigation of site and project-specific issues is recommended for those waterway segments with conflicts or complementary uses which are identified in this report.

Figure VIII - A

Reservoir Action Links to Hydropower, Water Supply
Flood Control and Recreation
(For segments with water availability conflicts)

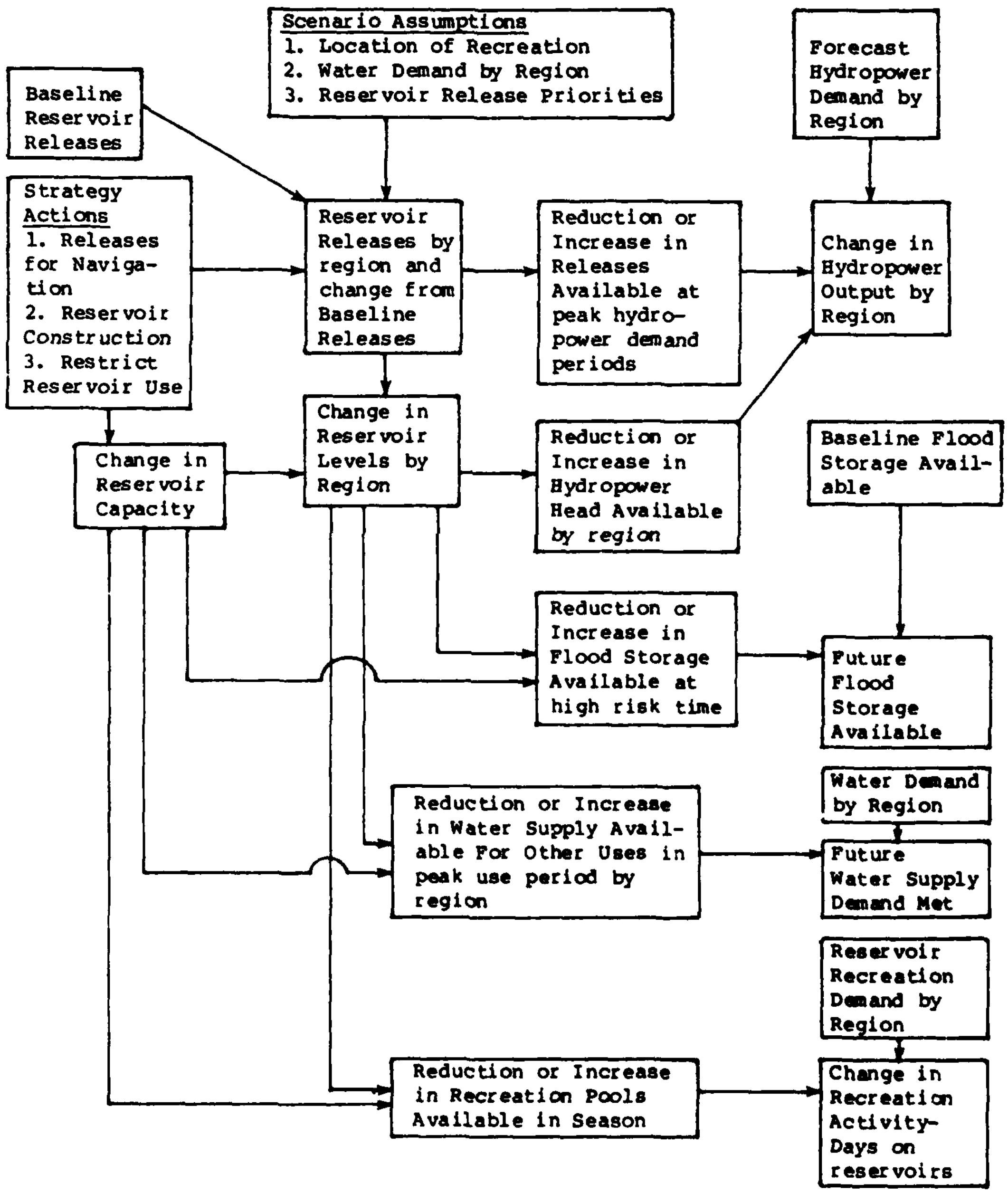


Figure VIII - B

Lock and Dam Action Links to Recreation

(All segments with locks)

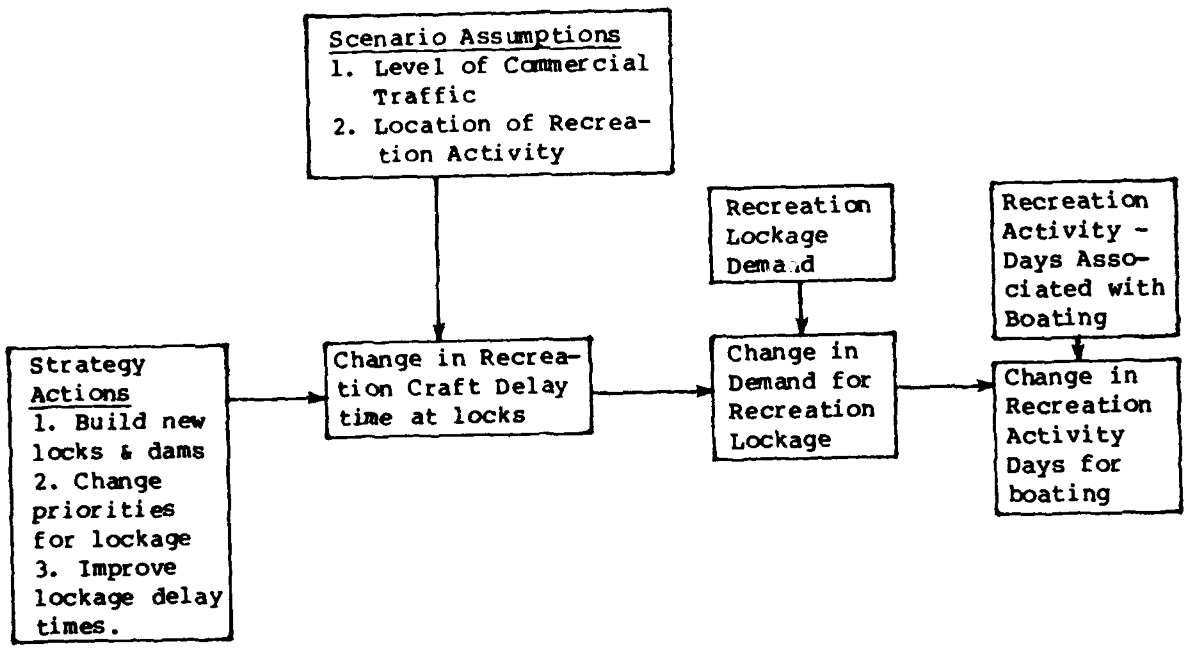
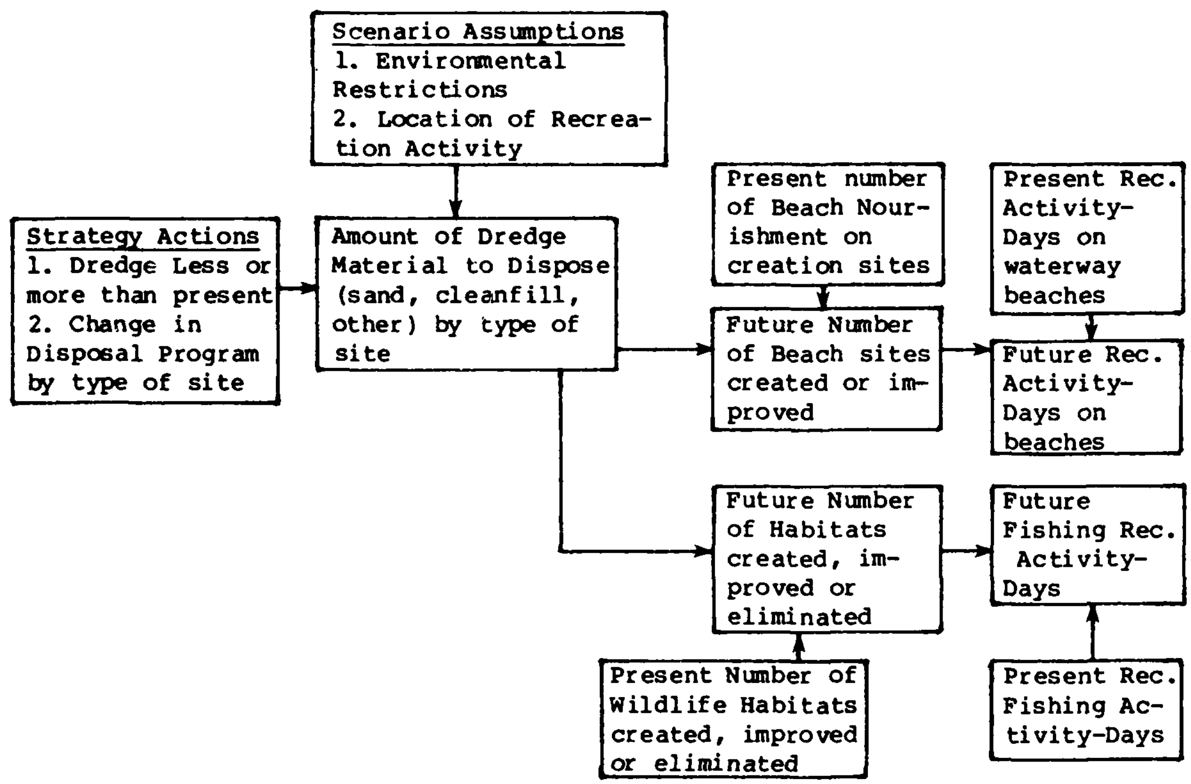


Figure VIII - C

Dredging Action Links to Recreation & Fish & Wildlife

(All segments with dredging)



GLOSSARY OF TERMS

GLOSSARY OF TERMS

A and C Canal: Albemarle and Chesapeake Canal

ACF: Apalachicola-Chattahoochee - Flint (river system)

anadromous species: fish that live in the ocean but spawn in rivers

analytic segment: waterway segment defined for NWS analysis purposes

APC: Alabama Power Company

aquatic habitat: water environment (river, lake or ocean)

aquifer: subsurface geological stratum containing water

approach channel: channel leading to a structure such as a lock

ASA: aggregated subarea for the National Water Assessment analysis

authorized depth: the designed minimum channel depth of a waterway

ballast discharges: pumping out of ballast tanks in sea-going vessels

bank stabilization: reduction of bank erosion by structural means

beach nourishment: use of dredged sand to increase beach area

biota: organisms inhabiting an ecosystem

brackish: moderately saline

breakwater: structure placed at the entrance to a port to reduce wave action

bubblers: devices that prevent icing by releasing streams of bubbles

CA: California Aquaduct

C and D Canal: Chesapeake and Delaware Canal

canalized segment: waterway composed of slackwater pools

carryover storage (in reservoirs): water remaining in a reservoir from one year to the next

CBHM: Chesapeake Bay Hydraulic Model

cfs: cubic feet per second

channel: part of a waterway with specific dimensions designed for commercial navigation

channel alignment: location and orientation of the channel

channelized: provided with a channel

COE: U. S. Army Corps of Engineers

conflict (with navigation): interference of a water use with navigation use or vice versa

control structures: structures designed to control water flow

controlling depth: actual minimum depth of a waterway at its shallowest point

consumption (water): net depletion, including evaporation, but excluding return flows

Corps: U. S. Army Corps of Engineers

cutoff: channel realignment to by-pass a curve

cut: division of a tow into two or more sections for passage through a lock

depletion: reduction in available water (usually annual)

detrital input: material carried downstream into a waterway

development corridor: linear area of concentrated land use development

discharge: flow out of a waterway or tributary

district: (Corps) administrative area below a division

division: principal Corps administrative unit

DOE: Department of Energy

DOT: Department of Transportation

double chamber locks: two parallel locks in one location

dredged material: material dredged up and deposited

dredging: using a dredge to maintain or create a waterway

EDP: electronic data processing (equipment)

effluents: liquid outflows

EIS: Environmental Impact Statement

Element B: NWS element concerning economic forecasts

Element Kl: NWS element concerning engineering and costs

Element M: NWS element concerning environmental analysis

EPA: Environmental Protection Agency

estuary: area of mixing between fresh and salt water

ETSI: Energy Transport Systems Inc. (pipeline)

exchange lockage: second lockage accomplished with a tow entering in the opposite direction

F and W: fish and wildlife

FERC: Federal Energy Regulatory Commission

fleeting activity: breaking or making up tows or temporary barge mooring

flood control: reduction of flood flows by storage of flood waters in reservoirs

flood plain: area adjacent to a river subject to flooding

flow distribution: probability distribution of flow volumes

flow regulation: control of waterway flow through the timing of reservoir releases

fly exchange lockage: lockage where vessel enters from the opposite direction without waiting

free-flowing: stretch of river with no pools or dams

freshwater gradient: direction of flow of freshwater (toward a canal)

full service (to navigation): flow levels defined for the Missouri River to provide adequate channel depth

gauge height: measurement of river stage at a selected gauge

GDM: General Design Memorandum, the Corps' principal project design document

GIWW: Gulf Intracoastal Waterway

GREAT: Great River Environmental Action Team

groundwater mining (or overdrafting): reduction of groundwater levels by pumping

groundwater reservoir: aquifer with water storage characteristics

guidewalls: walls leading to a lock to aid entry

head differentials: water height difference on two sides of a barrier

hydraulic barrier: structure to prevent water flow

hydraulic gradient: direction of water flow (toward a canal)

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hydraulic simulation model: model providing an analog of water flow in a given system

hydropower capacity: maximum electrical generation potential

hydropower peaking: generating power only at peak periods of the day or week

ice booms: devices to restrict the movement of ice at critical waterway sites

IJC: International Joint Commission for the St. Lawrence Seaway

inactive storage: reservoir water not available for releases

instream water demand: non-consumptive water use (e.g., hydropower, recreation)

interbasin transfers: water transported from one river basin to another

IWR: (Corps) Institute for Water Resources

L/D: Lock and Dam

LMVD: (Corps) Lower Mississippi Valley Division

lock: structure associated with a dam which allows vessels to pass

lock capacity: measure of the ability of a lock to pass vessels or freight

lock chamber: part of a lock where the water level is raised or lowered for a lockage

lockage: passage of one or more vessels through a lock

lockage cycle: the passage of a lock from up or down position to the other position and back

lockage water requirements: the amount of water used in lockage cycles

low flow augmentation: the release of water to increase flow in low flow periods.

minimum flow requirements: lowest legal or traditional flows specifical for a water way.

minimum service (to navigation): flow levels defined for the Missouri River to provide minimum channel depth

minimum stream flow envelope: graphic form of the sum of all minimum flow requirements over the year

mitigation measures: steps to prevent negative impacts of major actions

mgd: millions of gallons per day

mlg: mean low gulf, water height index

mooring cells: structures provided for vessels or tows in waiting areas

multivariate regression model: set of mathematical relationships derived from the use of this statistical technique

NAD: (Corps) North Atlantic Division

national waterway system: all commercially navigable waterways under the authority of the Corps of Engineers

navigable reaches: river stretches deep enough for commercial navigation

navigation facilities: structures provided primarily for commercial navigation

navigation need satisfaction ratio: analytic measure defined as the ratio of flow in a low flow month to lockage water requirements on a waterway

navigation releases: reservoir releases to provide flow for navigation purposes

navigation season: length of time during the year when a waterway is open for commercial navigation

NED: (Corps) New England Division

NOAA: National Oceanic and Atmospheric Administration

NPD: (Corps) North Pacific Division

non-structural changes: changes in operation or policy without a construction component

NTSB: National Transportation Safety Board

NWA: Second National Water Assessment, carried out by the Water Resources Council

NWS: National Waterway Study

NWS Inventory: data collected by the Corps for the NWS

OBERS data: Projections of economic activity in the U. S., jointly prepared by the U. S. Department of Commerce and the U. S. Department of Agriculture

open pass conditions: down position of a saltwater barrier allowing vessels to pass freely

oxbow lakes: lake created when a river meander is cut off by a new channel

OCZM: Office of Coastal Zone Management

pool: navigable water area behind a lock and dam

ppm: parts per million

ppt: parts per thousand

PMS: (Corps) Performance Monitoring System, collecting data on lockages

r2value: statistical measure of the amount of variation explained by an equation

recreation facilities: structures built primarily for recreation use

region: NWS reporting unit composed of several segments

reservoir: water area impounded by a dam (not commercially navigable)

resident species: fish normally inhabiting a waterway

river alluvium: soils deposited in a river bed

river basins: drainage area flowing into a river

river stage: height of a river measured at a specific reference point

river training: actions to control river flow so that channel sedimentation is minimized

river training structures: structures such as wing dams used for river training

RRMS: (Corps) Recreation Resources Management system

SAD: (Corps) South Atlantic Division

saline: containing salt

salt water intrusion: salt water entering a formerly freshwater zone

saltwater wedge: saltwater layer found in most estuaries

scenario: set of possible future conditions for NWS purposes

SCS: Soil Conservation Service

SCORP: State Comprehensive Outdoor Recreation Plan

season length (navigation): annual duration of commercial navigation on a waterway

SED: (Corps) South Eastern Division

segment: length of navigable waterway for use of NWS

SEPA: Southeast Power Administration

significant conflict: conflict with readily observable effects

slackwater: water held behind a dam for a navigation pool

slurry pipeline: pipeline for transporting powdered material in solution

SPD: (Corps) South Pacific Division

strategy action (or measure): action to improve or maintain a waterway

stream bed gradient: slope of a stream bed

stream bed substrate: geological layer beneath a stream

structural actions: actions involving construction

submerged sill: underwater salt water barrier

sub regions: part of an NWA region (usually an ASA)

sub segment: part of a waterway segment

SWD: (Corps) Southwest Division

TDS: total dissolved solids, a measure of salinity

Tenn-Tom: Tennessee-Tombigbee waterway

tow: group of barges propelled by a tow boat

turnback lockage: lockage requiring chamber to return to former level

TVA: Tennessee Valley Authority

USBR: United States Bureau of Reclamation (now Water and Power Resources Service)

USCG: United States Coast Guard

USDA: United States Department of Agriculture

user charge: payment assessed on a (water) user

user day: measure of the recreation participation of one person at sometime during a day

USGS: United States Geological Service

Water budget: allocation of uses to water supply

waterway: part of the commercially navigable waterway system

WES: (Corps) Waterways Experiment Station

WRC: Water Resources Council

FOOTNOTES

FOOTNOTES

1. Oklahoma Water Resources Board. Oklahoma Comprehensive Water Plan, 1980.

2. Oklahoma Water Resources Board. "Feasibility Studies of Conveyance." Element II of the Oklahoma Comprehensive Water Plan, 1980.

3. U. S. Army Corps of Engineers, Baltimore District. Chesapeake Bay Future Conditions Report, 1977.

4. Ibid.

5. U. S. Department of Interior, Geological Survey. Water Resources of the Delmarva Peninsula. Professional Paper No. 822, 1973.

6. Hershman, M. J. "Louisiana Wetlands Prospectus: Conclusions, Recommendations, and Proposals of the Louisiana Advisory Commission on Coastal and Marine Resources." Louisiana Advisory Commission on Coastal and Marine Resources, Baton Rouge, 1973.

7. U. S. Army Corps of Engineers, New Orleans District. Operations and Maintenance in the Mermentau Basin. Draft Environmental Impact Statement, 1979.

8. U. S. Army Corps of Engineers, New Orleans District. Operations and Maintenance on Four Projects Located South of the GIWW in Terrebonne Parish, Louisiana. Composite Environmental Impact Statement, 1975.

9. U. S. Army Corps of Engineers, Sacramento District. Sacramento River Deep Water Ship Channel. Draft Feasibility Report and Environmental Impact Statement, 1979.

10. CH2M-Hill. Salinity Study - Suisun Bay/Delta. Prepared under contract with the U. S. Army Corps of Engineers, San Francisco District, 1976.

11. The Tennessee - Tombigbee Waterway is still under construction. Thus, as yet there are no recreation data for this segment. It is, however, expected to generate significant amounts of recreational activity in the future.

12. Boating Industry Association. "A Recreational Boating View of Coastal Management." Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, July, 1976.

13. U. S. Army Corps of Engineers (St. Paul, Rock Island, and St. Louis Districts), Upper Mississippi River Basin Recreational Craft Locks Study, Stage II Planning Report, September 1977.

14. Howard, Needles, Tammen and Bergendoff, Recreational Craft Locks Study, U. S. Army Corps of Engineers (St. Paul District), October 1978.

15. GREAT I Recreational Working Group, "Upper Mississippi Dredged Material Disposal Site Recreational User Assessment," December 1978, p. 19.

16. U. S. Army Corps of Engineers, Vicksburg District. Greenville Harbor, Mississippi. General Design Memorandum No. 1, 1975.

17. Great Lakes Basin Commission. Great Lakes Basin Framework Study Report. Ann Arbor, 1976.

BIBLIOGRAPHY

BIBLIOGRAPHY

Anderson, Dorothy H., Earl C. Leatherberry and David W. Lime. "An Annontated Bibliography on River Recreation," North Central Forest Experiment Station, United States Department of Agriculture, March, 1979.

Anderson, David L. and Ruth S. Carey. "The Impact of Proposed Coal Slurry Pipelines on Regional Rail Coal Traffic Through the Year 2003," Data Resources, Inc., 1979.

Antle, Lloyd G. "Recreation at the McClennan-Kerr Arkansas River Navigation System." Water Resources Bulletin, Vol. 15, No. 5 (October, 1979), 1408-1417.

Arkansas River Basin Coordinating Commission, Report on 1978 Activities, United States Army Corps of Engineers, Southwest Division, January, 1979.

Arkansas, State of, Water Resources Development, 1978.

Badger, Daniel D., Dean F. Schreiner and Ronald W. Presley. Analysis of Expenditures for Outdoor Recreation at the McClellan-Kerr Arkansas River Navigation System. IWR Contract Report No. 77-4, December, 1977.

Battelle Laboratories. Environmental Assessment: West Coast Deepwater Port Study, United States Army Corps of Engineers, San Francisco District, June, 1973.

Baumann, D. D. "The Recreational Value of Domestic Water Supply Reservoirs: Perception and Choice," Department of Georgraphy Research Paper No. 121, University of Chicago.

Bay Conservation and Development Commission. Recreation On and Around San Francisco Bay. January, 1968.

Bayha, K. "Instream Flow Methodologies for Regional and National Assessments: A State of National Assessments: A State of the Art Review." Insteam Flow Information Paper No. 7, December, 1978.

Bayha, K. "Instream Flows - The Big Picture" in Instream Flow Needs, Vol. I, American Fisheries Society, September, 1976, pp 95 ff.

Becker, Robert M., et. al. Upper Mississippi Dredge Material Disposal Site: Recreational User Assessment Contract Report to the Great River Environmental Action Team and the St. Paul District, United States Army Corps of Engineers, November, 1978.

Becker, Robert H. "River Use Density and Visitor Satisfaction: An experimental explanation." Paper presented at the Leisure Research Symposium, National Recreation and Parks Association, Las Vegas, Nevada, October 3, 1977.

Bishop, Doyle W. and Robert Aukermann. "Water Quality Criteria for Seclected Recreational Uses." Water Resource Center Research Report No. 33, University of Illinois, Urbana-Champaign, (undated).

Boating Industry Associations. "A Recreational Boating View of Coastal Management." Office of Coastal Zone Management, National Oceanic and Atomospheric Administration, July, 1976.

Bonneville Power Administration, United States Department of Energy, Power Outlook, 1979.

Bowser, David J., et. al. "Shorefront Access and Island Preservation Study." Office of Coastal Zone Management, NOAA, November, 1978.

California, State of, Department of Water Resources, "Delta Water Facilities," 1978.

California, State of, Water Resource Development, 1978.

California, State of, Department of Boating and Waterways. A Guide to California Boating Facilities, 1979.

California, State of, Department of Parks and Recreation. California Comprehensive Outdoor Recreation Plan, February, 1974.

California, State of, Department of Parks and Recreation. California Park System Plan: 1980 Draft, September, 1979.

CH2M - Hill, Salinity Study - Suisun Bay/Delta Contract with Corps of Engineers, San Francisco District, 1976.

Chubb, Michael and Holly, 1974 Michigan Recreational Boating Study. Recreation Resource Consultants, for the Waterways Commission and the Law Enforcement Division, Michigan Department of Natural Resources, September, 1975.

Chubb, Michael and Eric II. Bauman, "The Rivers Method, A Pilot Study of River Recreation Potential Assessment." Department of Geography, Michigan State University, East Lansing, Michigan, 1976.

Clawson, Marion, and Jack L. Knetsch, The Economics of Outdoor Recreation. Baltimore: John Hopkins Press, 1966.

Coastal Zone Information Center. Bibliography on Estuaries/Wetlands, Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, August, 1979.

Coastal Zone Information Center. Bibliography on Hazards, Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, August, 1979.

Colette, W. Heady, and E. K. Nicol. The Impact of Water Rights and Legal Institutions on Land and Water Use in 2000, Iowa State University, 1976.

Columbia River Water Management Group, Columbia River Water Management Report, 1974 and 1977.

Coomes, R. T., Development of a Comprehensive Multipurpose Reservoir Regulation Plan for the Arkansas River Basin, Corps of Engineers Southwestern Division, Dallas, Texas, 1979.

Coomes, T., R. Hula and R. Copley. Analysis of Operation Plans for the Arkansas River Basin System or Reservoirs, presented at the National Workshop on Reservoirs Systems Operation, Boulder, Colorado, August 13-17, 1979.

Coplacd, B. J. "Effects of Decrease Reuse Flow and Estuarine Ecology." JWPCF 38, 1966, pp. 1831-1839.

Copley, R. Analysis of Operation Plans for the Arkansas River Basin System of Reservoirs, United States Army Corps of Engineers, Tulsa District, 1979.

Coughlin, Robert E., David Berry and Pat Cohen. Modelling Recreation Use in Water-Related Parks, Regional Science Research Institute, Philadelphia, Pa., October 1, 1978.

Culver, Charles and C. B. Millham. "Energy Loss and Replacement Cost of Navigation of the Snake-Columbia Rivers," Environmental Research Center, Washington State University, 1979.

Cushing, E. M., I. H. Kantrowitz, and K. R. Taylor. United States Geologic Survey, Water Resources of the Delmarva Peninsula, 1973.

Ditton, R. B., T. L. Goodale and P. K. Johnsen, "A Cluster Analysis of Activity, Frequency and Environment Variables to Identify Water-Based Recreation Types," Journal of Leisure Research, Vol. 7, No. 4, 1975, pp. 282-295.

Ditton, Robert B. and Mark Stephens, Coastal Recreation: A Handbook for Planners and Managers, Office of Coastal Zone Management, National Oceanic and Atomospheric Administration, January, 1976.

East Florida Regional Planning Council. PLAN: Open Space and Recreation, April, 1973.

El Sayed, S. Z. "Hydrological and Biological Studies of the Mississippi River - Gulf Outlet Project." Texas A & M, Ref. 61 - 20F, 1961.

ERDA, Synthetic Liquid Fuels Development: Assessment of Critical Factors, 76-129/1, Vol. 1, 1976.

Fleener, George C. and Mary Beth Gogel. Mississippi River Recreational Facilities Guide: Minneapolis, Minnesota to the Month of the Ohio River. Upper Mississippi River Conservation Committee, (undated).

Florida Department of Commerce. Florida Ports and Waterways Directory, 1973.

Florida Department of Natural Resources, Coastal Zone Population and Land Use Analysis, June, 1976.

Frazer, J. C., "Regulated Discharge and the Stream Environment" in River Ecology and Man. Oglesby, Carlson, McCann ed. Academic Press, 1973, pp, 263-286

Fuessle, R., E. Brill, G. Stout, and K. Wojnarowski "Power Development in the Ohio Basin," Journal of the Water Resources Planning and Management Division, ASCE, November, 1978.

GAI Consultants, An Engineering/Planning Assessment of Selected Aspects of the Plan for a Nation Waterways Study, Draft Report D, October, 1978.

Garrison, Charles B., "A Case Study of the Local Economic Impact of Reservoir Recreation," Journal of Leisure Research, Vol. 6, No. 4, 1974, pp. 7-19.

Great Lakes Basin Commission. Great Lakes Basin Framework Study Report, Ann Arbor, 1976.

Great Lakes Basin Commission. Commercial Navigation, Appendix C9, Great Lakes Basin Framework Study, 1975.

Great Lakes Basin Commission. Recreational Boating, Appendix R9, Great Lakes Basin Framework Study, 1975.

Great Lakes Basin Commission. Outdoor Recreation, Appendix 21, Great Lakes Basin Framework Study, 1975.

Great River Environmental Action Team. GREAT I: Interim Status Report, (Head of Navigation of Guttenberg, Iowa), March, 1978.

Great River Environmental Action Team. GREAT I: Activity Summary, August 1979.

Great River Environmental Action Team. GREAT II: An Inter-Agency Approach to River Management, Preliminary Feasibility Report, September, 1978.

Green, Gordon, Ivan Jones, and Merrill Schultz. Regulation of the Columbia Basin Reservoir System. ASCE Workshop on Reservoir Systems, 1979.

GSWM, Inc., Tygart Lake Master Plan: Design Memorandum No. 1, Prepared for Pittsburgh District, United States Army Corps of Engineers, December, 1976.

Gum, Russel L. and William E. Martin. "Problems and Solutions in Estimating the Demand for and Value of Outdoor Recreation." Natural Resources Journal, Vol. 9, 1969, 1976-211.

Hanke, S. and Boland, J., "Water Requirements or Water Demands", Journal of the American Water Works Association, November, 1971, pp. 677-681.

Harza Engineering Company, "Analysis of Energy Projections and Implications for Resource Requirement," Prepared for Missouri River Basin Commission, 1976.

Hensley-Schmidt, Inc., Divide Section Recreational Master Plan. Design Memorandum No. N-5, Prepared for United States Army Corps of Engineers, Nashville District, October, 1978.

Hershman, Marc, et. el., Under New Management: Port Growth and Emerging Coastal Management Programs, University of Washington Press, 1978.

Hitchcock, Henry, Analytical Review of Research Reports on Social Impacts of Water Resources Development Projects, Institute of Water Resources Contract Report 77-3, March, 1977

Howard, Needles, Tammen and Bergendoff. Recreational Craft Locks Study/Selected Alternatives on Upper Mississippi River from Minneapolis to Guttenberg, United States Corps of Engineers, St. Paul District, October, 1978.

International Great Lakes Levels Board, Regulation of Great Lakes Water Levels, Appendix D, "Fish, Wildlife and Recreation," 1973.

IWR, A Tale of Three Cities. IWR Research Report No. 77-Rw, December, 1977.

IWR, Population Change, Migration and Displacement Along the McClellan-Kerr Arkansas River Navigation System. IWR Contract Report No. 77-5, December, 1977.

IWR, Recent Developments in the McClellan-Kerr Arkansas River Navigation System Area. IWR Research Report No. 77-R1, April, 1977.

James, Douglas, L. "Economic Optimization and Reservoir Recreation," Journal of Leisure Research, Vol. 2, No. 1, 1970, pp. 16-29.

Kadlec, J. A. "Methodologies for Assessing Instream Flows for Wildlife," Instream Flow Needs, Vol. I. American Fisheries Society, 1976, pp. 355-363.

Kasperson, R. "Political Behavior and the Decision-Making Process in the Allocation of Water Resources Between Recreational and Municipal Use," Natural Resources Journal, Vol. 9, 1969, pp. 176-211.

Krutilla, John V. and Anthony C. Fisher. The Economics of Natural Environments. Baltimore: John Hopkins Press, 1975.

Lentnek, Barry, Carlton S. Van Doren and James R. Trail. "Spatial Behavior in Recreational Boating," Journal of Leisure Research, Vol. 1, No.2 (Spring, 1969, pp. 103-124.

Louisiana Advisory Commission on Coastal and Marine Resources, Louisiana Department of Transportation and Development, Louisiana Wetland Prospectus, 1973.

Louisiana, State of, Interagency ad hoc Study Group. Report on Mississippi River Flow Requirements, 1975.

Louisiana, State University, Center for Wetland Resources, Louisiana Dept. of Transportation and Development, Barataria Basin: Salinity Change and Oyster Distribution, 1976.

Marks, David H. "Preliminary Assessment of Potential Changes in Water Use and Their Implications for Navigation," September, 1979.

McCown, Brent, Kent Butler and Bill Gates, A Documentation of the Resource Information Package, GRASP, and Its Application to the Lake Superior Shoreline, Institute of Environmental Studies, University of Wisconsin, 1975.

Midwest Research Institute, Methodology and Forecasts of Recreation Use and Small Craft Lockages on the Upper Mississippi River, Final Report, Volumes I & II. Prepared for St. Paul District Corps of Engineers, July, 1978.

Midwest Research Institute, Potential Feasibility of Marina Concession Areas Along the Tenn-Tom Waterway, Final Report. Department of Army Corps of Engineers, Mobile District, August, 1977.

Mischon, Raymond M. and R. Chris Wyatt. Development of a Decision-Oriented Recreation User Information System, Midwest Research Institute, Kansas City, Missouri, October, 1978.

Mischon, Raymond M. and R. Chris Wyatt. Handbook for Conducting Recreation Surveys and Calculating Attendance at Corps of Engineers Projects, Midwest Research Institute, Kansas City, Missouri, May, 1979.

Mississippi River Commission, West Texas & Eastern New Mexico Water Import Study, Summary Report, October, 1973.

Mississippi River Commission, West Texas and Eastern New Mexico Water Import Study. Summary Report. 1973.

Missouri River Basin Commission, Water Availability Assessment for Coal Technology Requirements, Upper Missouri River Basin, 1978.

Missouri River Basin Commission, Yellowstone River Basin and Adjacent Coal Area Level B Study, 1978.

Missouri River Basin Commission, Water and Related Land Resources in the Missouri River Basin: Present and Future Uses and Associated Problems and Issues. Technical Memorandum No. 2, 1975 National Water Assessment, August, 1976.

Missouri River Basin Commission, Missouri River Flood Plain Pilot Study, St. Joseph to Kansas City, November, 1977.

Missouri River Basin Commission, 1979 Priorities Report, January, 1979.

Missouri River Basin Commission, Proposal for a Special Study Concerning a Flood Plain Management Program for the Missouri River Flood Plain, June, 1979.

National Academy of Sciences, Assessing Demand for Outdoor Recreation, Government Printing Office, 1975.

Nicol, K., E. Heady, and H. Madser. Models of Soil Loss, Land and Water Use, Spatial Agricultural Structure and the Environment, Iowa State University, 1974.

Oceanographic Institute of Washington, Survey of Marine Boat Launching and Moorage Facilities in Washington, August, 1978.

Ohio River Basin Commission, Monogahela River Basin Water and Related Land Resources Study Report and Environmental Impact Statement, July, 1975.

Ohio River Basin Commission, Green River Basin Comprehensive Coordinated Joint Plan, April, 1977.

Ohio River Basin Commission, The Ohio Main Stem Water and Related Land Resources Study Report and Environmental Impact Statement, October, 1978.

Ohio River Basin Commission, Allegheny River Basin Draft Environment Impact Statement, July, 1979.

P. Weddell, Copley International, The Market Structure of the Southern California Water Industry, for the Office of Water Resources Research, United States Dept. of the Interior, La Jolla, California, 1974.

Pacific Northwest River Basin Commission, Handbook of Inventory Information and Source Material, November, 1977.

Pacific Northwest River Basin Commission, Power Planning Committee, Seasonality of River Use on the Columbia and Lower Snake Rivers, December, 1975.

Pacific Northwest Utilities Conference Commission, West Group Forecast of Power Loads and Resources, 1979.

Peat, Marwick and Mitchell. North Coast Harbor Study, Prepared for the United States Army Corps of Engineers, San Francisco District, October, 1971.

Port of Portland, Recreational Boating Facilities Study, June, 1979.

Probstein, R. F. and H. Gold Water in Synthetic Fuel Production, M.I.T. Press, Cambridge, Massachusetts, 1978.

Roy F. Weston, Inc., Analysis and Methodology for Recreation Demand in Michigan, Wisconsin and Minnesota. Interim Report Prepared for St. Paul District, Army Corps of Engineers, (date unknown).

Roy Mann Associates, Recreational Boating on the Tidal Waters of Maryland. Report for the State of Maryland, Dept. of Natural Resources, *Energy and Coastal Zone* Administration, 1976.

Schaffer, Albert A., Ruth C. Schaffer and Gary M. Halter, "Social Impacts of McClellan-Kerr Navigation System: A Study of Public Sector Response to Water Resource Development," Texas A&M University, (undated).

Stanley Consultants, "Master Plan Design Memorandum No. 3: Navigation Pools 24, 25, and 26, Mississippi River," United States Army Corps of Engineers, St. Louis District, revised 1977.

Stroud, Richard H. and Henry Clepper, Marine Recreational Fisheries. Proceedings of the First Annual Marine Recreational Fisheries Symposium, 1976. Published by the Sport Fishing Institute, 1976.

Tennessee Valley Authority, Operation of TVA Reservoirs, Annual 1975, Knoxville, Tennessee, June, 1976

Tennessee Valley Authority, Operation of TVA Reservoirs, Annual 1979, Knoxville, Tennessee, June 1978.

Tenant, D. L. "Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources," in Instream Flow Needs, Vol. II, American Fisheries Society, 1976, pp. 359-375.

Texas, State of, Water Resources Development, 1978.

Transportation Study Commission, National Transportation Policies Through the Year 2000, Final Report, June, 1979.

Upper Mississippi River Basin Commission, Draft Report on the Upper Mississippi Main Stem, March, 1979.

Upper Mississippi River Basin Commission, Outdoor Recreation. Draft Report, March, 1979.

Upper Mississippi River Conservation Committee. Recreation Facility Inventory, 1978.

United States Army Corps of Engineers, Baltimore District, Chesapeake Bay Existing Conditions Report, 1973.

United States Army Corps of Engineers, Future Conditions Report, Chesapeake Bay, 1977.

United States Army Corps of Engineers, Chicago District, Final Feasibility Report, Manitowoc Harbor and Harbors Between Kenosha and Kewaunee, Wisconsin, September, 1977.

United States Army Corps of Engineers, Chicago District, Lake Michigan Regional Boating Survey and Analysis, January 1974.

United States Army Corps of Engineers, Chicago District, Northport Harbor Study, Door Country, Wisconsin. Phase I General Design Memorandum, March, 1976.

United States Army Corps of Engineers, Jacksonville District. Operation and Maintenance Reconnaissance Report on Continued Federal Maintenance of the Intra-Coastal Waterway, Jacksonville to Miami, Florida, 1979

United States Army Corps of Engineers, Jacksonville District. Survey Review Report on Central and Southern Florida Small Boat Navigation, 1968.

United States Army Corps of Engineers, Louisville District, Ohio River Access Site Report, Louisville, 1977.

United States Army Corps of Engineers, Louisville District, Ohio River Navigation Charts from Cairo, Illinois to Foster, Kentucky. Louisville, 1979.

United States Army Corps of Engineers, Louisville District, Final Environment Impact Statement, Clark Maritime Centre, Jeffersonville, Clark Country, Indiana Ohio River Mile 597, February, 1979.

United States Army Corps of Engineers, Missouri River Division, Main Stem Reservoir Regulation Studies, 1974

United States Army Corps of Engineers, Missouri River Division, Annual Operating Plan, 1978.

United States Army Corps of Engineers, Missouri River Division, Missouri River Main Stem Reservoir Regulation Manual, Rev. 1975.

United States Army Corps of Engineers, Missouri River District, Missouri River Main Stem Reservoir, 1978-79 Annual Operating Plan, August, 1978.

United States Army Corps of Engineers, Buford Reservoir Regulation Manual, (undated).

United States Army Corps of Engineers, Mobile District, Coordination Report on Navigational Improvements for Apalachicola River Below Jim Wodniff Dam, Florida, November, 1978.

United States Army Corps of Engineers, Mobile District, Apalachicola River Basin - Reservoir Regulation Manual, Appendix B, (undated).

United States Army Corps of Engineers, Mobile District. Supplement to Project Design Memorandum GDM for Canal Section. Design Memorandum No. 5, (undated).

United States Army Corps of Engineers, Mobile District. Tennessee-Tombigbee Waterway. Mobile, 1977.

United States Army Corps of Engineers. Tennessee-Tombigbee Waterways Recreational Facilities: Pertinent Data. (undated).

United States Army Corps of Engineers, Mobile District. Restudy on Coosa River Navigation Project, 1977.

United States Army Corps of Engineers, Claiborne Reservoir Regulation Manual, 1972.

United States Army Corps of Engineers, Buford Reservoir Regulation Manual.

United States Army Corps of Engineers, Nashville District. Improvement of Navigation Conditions in the Lower Cumberland-Tennessee Rivers Below Barkley Canal, 1972.

United States Army Corps of Engineers, People and the Sound: Marine Transportation Planning Report. Part of the Long Island Sound Regional Planning Study. Prepared for the New England River Basin Commission, New Haven, Connecticut, February, 1975.

United States Army Corps of Engineers, New England Division, Navel Underwater Systems Center, DAMOS - Disposal Area Monitoring System Annual Data Report, 1970.

United States Army Corps of Engineers, New Orleans District, Draft EIS for O&M in Mermentau Basin, 1979.

United States Army Corps of Engineers, Report on Gulf Coast Deep Water Port Facilities - Texas, Louisiana, Missouri, Alabama and Florida. Environmental Appendices, 1973.

United States Army Corps of Engineers, New Orleans District. GIWW; Petit Anse, Tigre, Carlin Bayous and Bayou Grosse Tete, Louisiana. Final EIS, 1976.

United States Army Corps of Engineers, New Orleans District. Lake Pontchartrain, LA and Vicinity Hurricane Protection Project. Final EIS, 1974.

United States Army Corps of Engineers, New Orleans District. Vermilion Lock Replacement. GDM No. 1, 1977.

United States Army Corps of Engineers, New Orleans District. Deep Draft Access to the Ports of New Orleans and Baton Rouge. Feasibility Report, 1974.

United States Army Corps of Engineers, North Central Division. Great Lakes Region Inventory Report: National Shoreline Study, August, 1971.

United States Army Corps of Engineers, North Central Division. Water Resources Development in Minnesota, January, 1979.

United States Army Corps of Engineers, North Central Division. Water Resources Development in Wisconsin, Janury, 1979.

United States Army Corps of Engineers, North Central Division. Upper Mississippi River Navigation Charts, Chicago, 1978.

United States Army Corps of Engineers, North Pacific Division. Columbia River and Tributaries Review Study, August, 1974.

United States Army Corps of Engineers, North Pacific Division. Columbia and Lower Snake Rivers: Comprehensive Coordinated Joint Plan, January, 1976.

United States Army Corps of Engineer, North Pacific Division, Columbia River and Tributaries: Base System Description for the Mid 1980's, November, 1977.

United States Army Corps of Engineers, Ohio River Division, Ohio River Bank Erosion Study, July, 1977.

United States Army Corps of Engineers, Omaha District, Missouri River-Main Stem Reservoir System, Reservoir Regulation Manual, November, 1960.

United States Army Corps of Engineers, Ohio River Division, Draft Environment Impact Statement Ohio River Navigation Project Operation and Maintenance, December, 1978.

United States Army Corps of Engineers, St. Paul, Rock Island and St. Louis Districts, Upper Mississippi River Basin Recreational Craft Locks Study, Stage II Planning Report, September, 1977.

United States Army Corps of Engineers, St. Paul District, Methodology and Forecasts of Recreation Use and Small Craft Lockages on the Upper Mississippi River, Final Report, Vol. 1, 1978.

United States Army Corps of Engineers, Seattle District, Pleasure Boating Study, Grays Harbor and Willapa Bay, Washington, April, 1973.

United States Army Corps of Engineers, Seattle District Pleasure Boating Study, Puget Sound and Adjacent Waters. Prepared in Cooperation with the Washington State Dept. of Commerce and Economic Development and the State Parks and Recreation Commission, November, 1968.

United States Army Corps of Engineers, South Atlantic Division: National Shoreline Study: Region Inventory Report, South Atlantic Gulf Region, August, 1971.

United States Army Corps of Engineers, South Atlantic Division. Water Resources Development (1977 and 1979 editions).

United States Army Corps of Engineers, South Pacific Division. National Shoreline study: California Regional Inventory, August, 1971.

United States Army Corps of Engineers, South Pacific Division. Water Resources Development, January, 1979.

United States Army Corps of Engineers, Southwest Division, Recent Developments in the McClellan-Kerr Arkansas River Navigation System, 1977.

United States Army Corps of Engineers, Southwestern District Reservoir Control, Report on 1978 Activities Arkansas River Basin Coordinating Commission, January, 1979.

United States Army Corps Engineers, Southwestern Divisions, Arkansas River Basin Coordinating Committee - Report on 1978 Activities, January, 1979.

United States Army Corps Engineers, Tulsa and Little Rock Districts, McCellan-Kerr, Arkansas River Navigation System, August, 1978.

United States Army Corps of Engineers, Tulsa District. Land Use Allocations in Oklahoma, Tulsa, 1975.

United States Army Corps of Engineers, Pittsburgh District. Tygart Lake Reservoir Regulation Manual, November, 1976.

United States Army Corps of Engineers, Philadelphia District. Inland Waterway Delaware River of Chesapeake Bay. Final EIS, 1977.

United States Army Corps of Engineers, Portland District, Columbia River and Tributaries Review Study, 1977.

United States Army Corps of Engineers, Sacramento District, Analysis of Supply and Demand of Urban Oriented Non-Reservoir Recreation. IWR Research Report 76-R2, November, 1976.

United States Army Corps of Engineers, Sacramento District, "Salinity Conditions in Harbor and Ship Channel." Office Report, 1972.

United States Army Corps of Engineers, Sacramento District, Sacramento River Deep Water Ship Channel. Draft Feasibility Report and EIS, 1979.

United States Army Corps of Engineers, San Francisco District. Extension of Entrance to Islas Creek Channel: Detailed Project Report, October, 1975.

United States Army Corps of Engineers, San Franscisco District. Final Composite Environmental Statment on Maintenance Dredging of Existing Navigation Projects, Volumes I & II, December, 1975.

United States Army Corps of Engineers, San Francisco District, San Francisco Bay Area In-Depth Study. Contains the following Volumes:

Commodity Flow Analyis: Historical Commodity Movement, June, 1973.

Institutional Inventory, November, 1976.

New Facility Analysis, June, 1976

Vessels and Port Facilities Analysis: Inventory of Channels, Ports and Related Facilities, June, 1973.

Vessels and Port Facilities Capability Study, January, 1976.

United States Army Corps of Engineers, St. Paul District. Water Oriented Recreational Demand and Projections; Calculations for Western Lake Superior, June, 1978.

United States Army Corps of Engineers, Tulsa District. Port Verdigris 33 Inc. and Other Potential Development: Verdigris River Portion, McClellan-Kerr Arkansas River Navigation System, Draft Environmental Impact Statement, Tulsa, (undated).

United States Army Corps of Engineers, Tulsa District, Oologah Lake Regulation Manual, December, 1975.

United States Army Corps of Engineers, Tulsa District, Arkansas River Basin Lake Regulation Master Manual, 1976.

United States Army Corps of Engineers, Tulsa District, Oologah Lake, Verdigris River, Oklahome Lake Regulation Manual, 1975.

United States Army Corps of Engineers, Vicksburg District, Greenville Harbor, Mississippi, GDM No. 1 Plan Formulation, 1975.

United States Army Corps of Engineers, Walla Walla District, Irrigation Depletions/Instream Flow, 1976.

United States Coast Guard, Office of Boating Safety, Recreational Boating in the Continental United States in 1973 and 1976: The Nationwide Boating Survey, March, 1978.

United States Dept. of Agriculture, North Central Forest Experiment Station, Proceedings of the Symposium on River Recreation Management and Research, 1977.

United States Dept. of Agriculture, Weather and Water Allocation Study, 1979.

United States Dept. of Agriculture, Soil Conservation Service, Special Products Division, Livestock Water Use, July, 1975.

United States Dept. of Agriculture, Economics, Statistics and Cooperatives Service, Forest Service, Agricultural Resource Assessment System, Material Prepared for the 1975 National Water Assessment.

United States Dept. of Commerce & Louisiana Dept. of Transportation, OCZM, Louisiana Coastal Resources Programs, Draft EIS, 1979.

United States Dept. of Commerce, National Bureau of Standards, "Counties and Country Equivalents of the States of the United States," Federal Information Processing Standards Publication 6-2, September 15, 1973.

United States Dept. of Energy, Energy Information Administration, Inventory of Power Plants in the United States April, 1979, of Energy, Energy Information, Released May 25, 1979.

United States Department of Energy, Oak Ridge National Laboratory, A Nationwide Assessment of Water Quantity Impacts of the National Energy Plan, 1977.

United States Dept. of Energy, Office of Technology Impacts, Regional Assessment Division, Regional Issue Identification and Assessment, 1979.

United States Geological Survey, Index to Water-Data Activities in Coal Provinces of the United States, 1979.

United States Geological Survey, "Water Resources of the Delmarva Peninsula," Prof. Paper 822, 1973.

United States Dept. of Interior, "Progress Report Three on Water Policy Implementation Initiatives," Washington, D. C., May 10, 1979.

United States Dept. of Interior, Bureau of Mines, "Projects to Expand Fuel Sources in Eastern States - An Update of Information Circular 8725," Information Circular IC 8765, 1978.

United States Dept. of Interior, Bureau of Mines, "Projects to Expand Energy Sources in the Western States - An update on Information Circular 8719," Information Circular IC 8872, 1978.

United States Dept. of the Interior, Bureau of Outdoor Recreation, Lake Central Region. Upper Mississippi River Comprehensive Basin Study, Appendix K, Recreation, Ann Arbor, (undated).

United States Dept. of Interior, Bureau of Outdoor Recreation, Chesapeake Bay Future Conditions Report. Vol. 7: "Recreation," 1976.

United States Dept. of the Interior, Bureau of Reclamation, Critical Water Problems Facing the Eleven Western States, 1975.

United States Dept. of the Interior, Heritage, Conservation and Recreation Service, National Urban Recreation Study: Summary Report, February, 1978.

United States Dept. of the Interior, Office of the Assistant Secretary for Fish, Wildlife and Parks, Water Policy Implementation Task Force on Environmental Statutes Report, August, 1979.

United States Dept. of the Interior, Office of the Secretary, "Water Coast Sharing Proposal" sent to Congress, News Release, May 16, 1979.

United States Water Resources Council, Federal Register, "Water Resources Council-Water Project Review Function, Proposed Rules and Procedures of Implementation, Vol. 44, No. 34, February 16, 1979.

United States Water Resources Council, Federal Register, "Water Resources Council-Procedures for Evaluation of National Economic Development (NED) Benefits and Cost in Water Resources Planning (Level C) and Proposed Revisions to the Standards for Planning Water and Related Land Resources, Vol. 44, No. 102, May 24, 1979.

United States Water Resources Council, The Nation's Water Resources, The Second National Water Assessment, Washington, April, 1978.

United States Water Resources Council, Bureau of Census, United States Dept. of Commerce, Obers Projections, Vol. 3, Water Resources Regions and Sub-Areas, April, 1974.

Van Doren, Carl S. and Barry Lentnek. "Activity Specialization Among Ohio's Recreational Boaters", Journal of Leisure Research, Vol. 1, No. 4, 1969, pp. 296-315.

Water Resources Center, University of Wisconsin, Upper Mississippi River Basin Regional Recreation Assessment: A Proposal, University of Wisconsin, 1977.

Ward, J. V., "Effects of Flow Patterns Below Large Dams on Stream Benthas in a Review" in Instream Flow Needs, Vol. II. American Fisheries Society, 1976, pp. 235-253.

White, R. G., "A Methodology for Preliminary Stream Resource Maintenance Flow for Large Rivers," Instream Flow Needs, Vol. II, American Fisheries Society, 1976, pp. 376-386.

Wulfsberg, Rolf M. and Darryl A. Lang. Recreational Boating in the Continental United States in 1973: The Nationwide Boating Survey. United States Coast Guard, October, 1974.

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FINAL REPORT

ANALYSIS OF NAVIGATION RELATIONSHIPS TO OTHER WATER USES

APPENDIX

Analysis of Navigation Relationships to Other Water Uses

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Analysis of Navigation Relationships to Other Water Uses

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APPENDIX A

DETAILED METHODOLOGY FOR THE FLOW AVAILABILITY ANALYSIS

The following information is provided as detail of the Flow Availability Analysis. This information includes base data, segment selection, and analysis steps.

(a) Summary of NWA Forecasts

A preliminary screening of segments was made to select those to be analyzed for potential flow conflicts. This screening identified those segments with significant levels of commercial navigation and whose channel depths vary significantly with flows from upstream. This definition excluded those segments whose channel depths are determined by tidal action. Table A-1 shows those segments which were screened out at this point in the analysis.

The ASA's selected for inclusion in this analysis were chosen for one of two reasons. First, they could include, or be adjacent to, one of the NWS non-tidal analytic segments. Second, they could influence downstream water availability. ASA's which meet either of these criteria are important because water consumed in these ASA's is then not available to support navigation on an NWS segment. Water consumption in any of the other ASA's does not affect water availability for navigation except for slurry pipelines and canals, which are treated separately.

Data on water consumption in million gallons per day (MGD) were calculated for each ASA affecting a non-tidal segment of the navigable waterway system. Water consumption is defined by the NWA as net withdrawals. For agricultural use this includes evapotranspiration of the crop and incidental consumptive losses related to irrigation. Where there is a variation in consumption between an average hydrologic year and a "dry year" both projections were analyzed. The National Water Assessment defines a dry year as one in which the annual stream flow is exceeded

Table A-1

Segments Screened Out of the Water Availability Analysis

Segment No.	Waterway	Corps Division	Reason
7	Mississippi River: Baton Rouge to New Orleans	LMVD	Tidal
8	Mississippi River: New Orleans to Gulf	LMVD	Tidal
28	GIWW West One	LMVD	Tidal except for the fresh water section behind salt water barriers which has no water availability problem
29	GIWW West Two	SWD	Tidal
30	GIWW West Three	SWD	Tidal
31	GIWW East One	SED & LMVD	Tidal
32	GIWW East Two	SED	Tidal
33	Florida Gulf Coast	SED	Okeechobee waterway carries little commercial traffic. Rest is tidal
34	Houston Ship Channel	SWD	Tidal

Table A-1 (Cont.)

Segment No.	Waterway	Corps Division	Reason
39	Florida/Georgia Coast	SED	Altamaha carries no commercial traffic and Savannah carries little above tidal segment.
40	Carolina Coast	SED	Cape Fear carries insignificant commercial traffic above tidal segment.
41	Chesapeake & Delaware Bays	NAD	Tidal
42	New Jersey/ New York Coast	NAD	Delaware is tidal to head of navigation at Trenton. Hudson is tidal to Albany.
44	Upper Atlantic	NED	Connecticut River is tidal to head of commercial navigation at Hartford
50	Puget Sound	NPD	Tidal
52	Lower Columbia	NPD	Columbia is tidal to Bonneville. Willamette River has no commercial navigation.

Table A-1 (Cont.)

Segment No.	Waterway	Corps Division	Reason
53	Oregon/Washington Coast	NPD	Tidal
54	Northern California Coast	SPD	Tidal
55	San Francisco Bay	SPD	Tidal
56	Central/South California Coast	SPD	Tidal
57	South East Alaska Coast	NPD	Tidal
58	South Central Alaska Coast	NPD	Tidal
59	West & North Coasts of Alaska	NPD	Yukon, Kuskokwim, Kibuk and Noatak carry little commercial traffic
60	Western Pacific (Island Coasts)	SPD	Tidal
61	Caribbean (Island Coasts)	SAD	Tidal

NOTES: (1) Segment 28 through 34, 39 through 42, 44, 50 and 53 through 61 whose flows are strictly tidal over their commercially navigable reaches did not merit further consideration.

Table A-1 (Cont.)

NOTES: (2) According to Corps representatives in Mobil, the Altamaha, Savannah, and Cape Fear rivers all experience flows below authorized depths for at least part of their length. However, these rivers were not considered to have low flow problems because the few commercial craft that ply these rivers had sufficiently small drafts to allow them to navigate year round. The Altamaha carries mostly recreational craft above Wilmington (a deep draft port) and the Savannah has primarily fishing boats as commercial traffic. The Okeechobee waterway does contain fresh water between the two end locks (Franklin and St. Lucia) but it is primarily utilized by recreation and fishing craft nd has never experienced low flow conflicts, according to Corps District data.

(3) The Delaware River is tidal to Trenton. The Hudson River is tidal to Albany and is pooled with locks and dams upstream from Albany. The combination of drought conditions and extreme low tides on the Hudson could decrease depths one to two feet for a few hours a day but this would not have a significant effect on navigation. The Connecticut River is tidal to mile 60 and there is presently no commercial navigation above Hartford (mile 52).

80% of the time. Agricultural demands are the only uses which vary significantly between average and dry year conditions.

Data were organized in six user categories. These are modifications of the categories in the National Water Assessment. They have been rearranged so that primary emphasis can be given to the major water users which have the greatest probability of affecting navigation flows (see sample table in Exhibit A-1). The six categories are:

1. Domestic and Commercial are all private household and business consumption from both central and non-central systems.

2. Energy needs for water are identified in two subcategories: cooling and mining.

Cooling demand represents all water which is used for cooling in nuclear and fossil fuel-fired generating stations. Once-through cooling is not considered since it is not a consumptive use. Mining is the water needed for extraction and processing of energy sources. These projections do not include water consumption for coal conversion plants or other non-traditional energy sources. Forecasts of energy needs for water have been checked with other Department of Energy projections, in particular those contained in the Regional Issue Identification and Assessment, Final Draft, July 1979, Office of Technology Impacts, DOE.

3. Mineral demand for water is for extraction of metal ores and other non-metal materials. Water required for mining of fossil fuels is contained in the Energy category.

4. Industrial water use is for all process water used in manufacturing. Once-through cooling water or other wastewater discharges are not included.

5. Agricultural water requirements are also considered in two parts: livestock and irrigation. These values are based on modeling efforts at the Department of Agriculture which relate land and water requirements to economic activity and export levels taking into account

farming efficiency parameters such as soil types and the costs of production. Water demands for agriculture are also calculated for average and drought years.

6. Other, the final category, includes all the small miscellaneous uses which are not counted in the other areas. Examples of uses in this category are public and park lands, national forests, and fish hatcheries.

Table A-2 provides a list of those ASA's used in this analysis and the corresponding NWS segments. Table A-3 presents these ASA's in order by NWWS segments. Table A-3 presents these ASA's in order by NWS segment number.

(b) Analysis of Unit Water Use

This step examined the NWA data and other sources in order to identify important patterns of water use by river basin and also the major projects that could affect this use. Table A-4 provides a ranking by NWA Region (corresponding to major river basin) of water consumption categories. This analysis indicated that mining and livestock were never large enough to be a significant use and could be relegated to a miscellaneous category of other uses. The other five uses were highly ranked in at least one region, and would serve as the focus of more detailed analysis.

Further analysis was provided for unit water consumption, defined as follows:

1. Domestic and Commercial - in gallons/person/-year.

2. Power Plant Cooling - in gallons per giga-watt-hour generated.

3. Industrial - in gallons per dollar of earnings.

4. Agricultural - in gallons per irrigated acre.

Table A-2

Aggregated Subareas and NWS Segments Used in the Water Availability Analysis

ASA #	Principal Rivers or Lakes	NWS Segment
106	Lake Champlain	Upstream of 42
201	Mohawk - Hudson	42, 43
306	Chattahoochee	38
307	Alabama - Conecuh - Choctawhatchee	36
308	Tombigbee	35,37
401	South Lake Superior	47
402	West Lake Michigan	48
403	Lower Lake Michigan	48
404	East Lake Michigan	48
405	West Lake Huron	47
406	West Lake Erie	46
407	South Lake Erie	46
408	South Lake Ontario - St. Lawrence	45
501	Allegheny - Monongahela	16, 17
502	Ohio	11,12
503	Scioto - Muskingum	Upstream of 11, 12
504	Kanawa	18
505	Ohio - Green - Kentucky - Licking	13, 14, 15, 19, 20
506	Wabash - White	Upstream of 14, 15
507	Cumberland	21
601	Upper Tennessee	22
602	Lower Tennessee	22, 23
701	Upper Mississippi - Minnesota	1
702	Chippewa - Black - Wisconsin & Mississippi	1
703	Iowa - Des Moines - Rock & Mississippi	1
704	Illinois and Mississippi	1, 2, 9
705	Kaskaskia - Meramec - Mississippi	3
801	Middle Mississippi to Arkansas	4, 24
802	Lower Mississippi to Red	5, 25
803	Mouth of Mississippi - Calcasieu	6, 7, 26, 27
1001	Milk - Upper Missouri	10
1002	Sun - Upper Missouri	10
1003	Upper Missouri to Milk	Upstream of 10
1004	Yellowstone	Upstream of 10
1005	Upper Missouri to Nebraska	Upstream of 10
1006	James - Big Sioux & Missouri	Upstream of 10
1007	North - South Platte	Upstream of 10
1008	Platte to Missouri	Upstream of 10

Table A-2 (Cont.)

ASA #	Principal Rivers or Lakes	NWS Segment
1009	Middle Missouri	Upstream of 10
1010	Republican - Kansas	Upstream of 10
1011	Lower Missouri	Upstream of 10
1102	Upper Arkansas	Upstream of 24
1103	Middle Arkansas	Upstream of 24
1104	Verdigris - Lower Arkansas	24
1105	Canadian	Upstream of 24
1106	Upper Red	Upstream of 25
1107	Lower Red	25
1701	Bitteroot - Flathead - Upper Columbia	Upstream of 51
1702	Okonogan - Deschutes - John Day Middle Columbia	51
1703	Upper Snake	Upstream of 51
1704	Lower Snake	51
1705	Lower Columbia - Willamette - Rouge	51, 52
1802	Sacramento	55
1803	San Joaquin	55
1804	San Francisco Bay	55

Table A-3

ASA's Tributary to Non-tidal NWS Segments

NWS Segment segment)	Adjacent ASA	Upstream ASA (without NWS segment)
1	701, 702, 703, 704	-
2	704	-
3	705	-
4	801	-
5	802	-
6	803	-
7	803	-
8	803	-
9	704	-
10	1009, 1011	1001, 1002, 1003 1004, 1005, 1006 1007, 1008, 1010
11	502	-
12	502	503
13	505	-
14	505	506
15	505	-
16	501	-
17	501	-
18	504	-
19	505	-
20	505	-
21	507	-
22	601, 602	-
23	602	-
24	801, 1104	1102, 1103, 1105
25	802, 1107	1106
26	803	-
27	803	-
35	308	-
36	307	-
37	308	-
38	306	-
42	201, 106	-
43	201, 408	-
45	408	-
46	406, 407	-
47	405	-

Table A-3 (Cont.)

NWS Segment	Adjacent ASA	Upstream ASA (without NWS segment)
48	402, 403, 404	-
49	401	-
51	1702, 1704, 1705	1701, 1703
52	1705	-
55	1802, 1803, 1804	-

Table A-4

Domestic [illegible] nsumption

NWA Region	Population (Thousand) 1975	2000	Population Growth Factor of Increase	Domestic and Commercial Consumption Gals/person/yr 1975	2000	Consumption Unit Factor of Change
1	372	449	1.21	6,868	8,129	1.18
2	39,612	49,939	1.26	7,243	5,913	.82
3	25,423	34,680	1.36	14,443	15,850	1.10
4	30,391	36,351	1.20	6,317	7,049	1.12
5	21,158	24,791	1.17	7,107	7,200	1.01
6	3,565	4,615	1.29	7,167	7,118	.99
7	13,387	15,822	1.18	9,407	8,951	.95
8	6,417	7,142	1.11	19,510	20,340	1.06
10	8,832	10,042	1.14	13,845	13,773	.99
11	4,953	5,783	1.17	17,760	18,610	1.05
17	6,703	7,589	1.13	14,539	14,437	1.00
18	8,015	10,199	1.27	29,009	28,988	1.00

SOURCES: The Nation's Water Resources, the Second National Water Assessment by the United States Water Resources Council. Preliminary, April 1978, Statistical Appendix A-1, Tables 1, 1-01, 1-11, 1-18.

Unit factors for these major uses are provided for each NWA region in 1975 and 2000 in Tables A-4 to A-7. An additional table (A-8) is provided for coal mining and slurry pipelines water use data in the Upper Missouri River Basin, as this may be significant in the future under certain scenarios. It is clear from this table that coal slurry pipelines, if they are used, will account for the major water use compared with mining.

(c) Modification of Water Demand Forecasts

The water demand forecasts for each ASA upstream of or adjacent to each NWS segment were modified to reflect differences between the macro-economic forecasts inherent in the NWA forecasts and the macro-economic forecasts generated for the National Waterways Study. This was particularly significant for power plant cooling and irrigation water demands.

For power plant cooling, the NWS forecasts for power generation by types of plant (fossil or atomic) were disaggregated by ASA. Then the NWS demand for water consumption was computed, using the same unit demand relationships per gigawatt-hour as in the NWA forecasts.

For irrigation water demand the NWS macro-economic forecasts were compared with USDA model forecasts of future agricultural production, The closest USDA forecast to each NWS forecast (in terms of acres planted by crop) was selected, and this allowed a more disaggregated analysis of future water demand at the ASA level. The greatest amount of analysis was devoted to this aspect of water consumption due to its importance in overall future water demand.

The Department of Agriculture, Soil Conservation Service, has done extensive modeling of water demand for irrigation and livestock needs in support of the National Water Assessment. They have prepared forecasts of water demand for ten different scenarios to the year 2000. A summary of the ten scenarios and the assumptions for each is shown in Table A-9.

Table A-5

Cooling Water Consumed for Power Plant Cooling

NWA Region	Fossil and Nuclear Gigawatt Hours Generated		Gals. of Water Consumed/Kilowatt Hour Generated	
	1975	2000	1975	2000
1	56	0	0	0
2	195,067	898,343	.193	.261
3	220,101	1,757,891	.254	.385
4	182,992	821,162	.349	.615
5	299,003	1,049,004	.396	.589
6	48,763	247,258	.314	.617
7	112,704	665,279	.418	.591
8	53,363	365,708	.369	.290
10	55,851	434,552	.444	.535
11	45,189	269,720	.517	.438
17	9,602	252,958	.494	.496
18	17,102	100,468	.235	.498

SOURCES: NWA Preliminary, Statistical Appendix Volume A-1, Table 11B; Statistical Appendix Volume A-2, Part 2, Table 28.

Table A-6

Manufacturing Earnings and Efficiency of Industrial Water Consumption

NWA Region	Manufacturing Earnings (millions of dollars)		Earnings Growth Factor of Increase	Gallons Consumed Per Dollar of Earnings		Factor of Change
	1975	2000		1975	2000	
1	357	952	2.67	9.2	5.8	.63
2	52,527	105,598	2.01	4.2	4.7	1.12
3	25,954	64,366	2.48	8.6	14.4	1.67
4	62,657	126,511	2.02	8.6	5.9	.69
5	32,024	69,439	2.17	9.3	9.2	.99
6	4,519	11,560	2.56	12.0	16.2	1.35
7	18,4[illegible]	40,234	2.18	4.7	4.6	.98
8	5.159	12,580	2.44	22.9	17.0	.74
10	6,791	15,522	2.29	8.9	4.0	.45
11	4,102	10,058	2.45	10.7	9.1	.85
17	6,814	14,125	2.07	17.4	22.7	1.30
18	7,584	17,224	2.27	6.4	6.0	.94

SOURCES: NWA Preliminary Report, Statistical Appendix Volume A-1, Table 3A; Statistical Appendix, Volume A-2, Part 2, Table 23.

Table A-7

Irrigated Land and Efficiency of Irrigation

NWA Region	Acres of Irrigated Land (1000's)		Factor of Increase	Gals. (1000's) Consumed Yearly For Irrigation/Acre Irrigated Land				Factor of Change (Avg. Year)
	1975	2000		1975		2000		
				Avg.	Dry	Avg.	Dry	
1	1	1	1.00	365	365	365	365	1.00
2	264	476	1.80	271	335	271	336	1.00
3	2,035	3,040	1.49	478	617	432	556	.90
4	164	334	2.04	256	307	255	306	1.00
5	57	102	1.79	237	295	265	329	1.12
6	15	23	1.53	268	292	286	302	1.07
7	204	434	2.13	274	345	272	341	.99
8	1,986	2,862	1.45	568	635	417	473	.73
10	9,695	11,505	1.19	534	607	560	640	1.05
11	3,669	4,532	1.24	486	576	410	481	.84
17	6,186	7,759	1.25	651	821	622	784	.95
18	6,687	8,116	1.21	971	1,050	918	993	.95

SOURCES: NWA Preliminary, Statistical Appendix Volume A-1, Part 1, Table 6. Statistical Appendix, Volume A-2, Part 2, Table 23.

Table A-8

Potential Water Consumption By Coal in the Missouri River Basin

Activity	Water Consumption Or Water Transportation (millions of gallons) / Coal Mined or Transported (millions of tons)
Coal production - *no* reclamation	1.65
Coal production with reclamation	3.00
Coal slurry pipeline (transference)	240

Fast growth scenario - coal production in Region 10

	Coal Mined (millions of tons)	Water Consumed (millions of gals.)	% of Regional Total	Gals/Ton
1975	54	98	1.0	1.81
2000	1000	2500	12.6	2.50

SOURCES: Harza Engineering Company, "Analysis of Energy Projections and Implications for Resource Requirements: prepared for Missouri River Basin Commission," 1976.

Conversations with Bureau of Economic Analysis, Energy and Coal Production Applied Analysis Group staff, Washington, D.C.

Conversations with Energy Information Administration staff, United States Department of Energy, Washington, D.C.

Table A-9

USDA Model Assumptions for Water Demand Forecasts

	Years	Land Base	Wet soils Conversions	Irrigated acres	Water Supply	Irrigation Efficiency	Crop Yields	Domestic Demand	Export Demand	Gross Erosion	Livestock Waste Disposal	Regional Adjustment Constraints
Central Case OBERS E	1975 1985 2000	1969 Census of Agriculture	Convert 1.5%/yr. I, IIe, IIw	OBERS E (current trend)	No limit	Current practice	OBERS E	OBERS E	OBERS E	Not applicable	Not applicable	OBERS E
Low Export (OBERS E LP)	1985 2000	1967 CNI	Convert IIw, IIIw 90% CNI	do.	do.	do.	ISU	do.	do.	10 x T value 40 tons/ acre/year	Not restricted	0.7 1969 2.0 (1985 limits) 0.4 1969 (2000 limit)
Low Export (OBERS E LP) (water constraint)	2000	do.	do.	do.	Current use +70% outflow	do.	do.	do.	do.	do.	do.	do.
Moderate Export (OBERS E' LP)	1985 2000	do.	do.	Potential irrigable a/ 1969 Census of Agri-culture	do.	do.	do.	OBERS E'	OBERS E'	do.	do.	do.
High Export	do.	do.	do.	do.	do.	do.	do.	do.	High exports	do.	do.	do.
Land and water conservation	do.	do.	No conversion	do.	do.	Improved efficiency	do.	do.	OBERS E'	T value	do.	do.
Environmental Protection Moderate Export	do.	do.	do.	No minimum	Instream requirement preempts b/	Current practice	do.	do.	do.	do.	Waste disposal on land	do.
Environmental Protection Low Export	2000	do.	do.	do.	do.	do.	do.	OBERS E	OBERS E	do.	do.	do.
Energy development	do.	do.	Convert IIW, IIIw 90% CNI	do.	Energy development preempts	do.	do.	OBERS E'	OBERS E'	10 x T value 40 tons/ acre/year	Not restricted	do.
Moderate Export/ MCC	1985	do.	do.	Potential irrigable a/ 1969 Census of Agri-culture	Current use + 70% outflow modified c/	do.	do.	do.	do.	do.	do.	0.7 1969 2.0 (1985 limits)
Land conserva-tion/MCC	2000	do.	do.	do.	do.	do.	do.	do.	do.	2 x Td* value d/	do.	0.4 1969 6. (2000 limits)

NOTES: a/ Projected irrigable acreage includes public development with maximum placed on private irrigation development.
b/ Fish and wildlife instream flow requirements allowed to preempt irrigation use from surface water sources.
c/ Modifications resulting from regional study directors' review of 1975 and Central Case estimates.
d/ Except ASA 1009, loess area of Western Iowa, and ASA 1704, Palouse area of Washington and Idaho.

SOURCE: USDA, Soil Conservation Service.

The SCS forecasts, except for one case, utilize a linear programming model. After projecting the demand for food and fiber products the model satisfies this demand by allocating production to the different ASA's. The ASA with the lowest production cost is utilized first. Then if there is excess demand the ASA with the next lowest production cost is used and so on. Parameters used in the model include land use, soil types, availability of water, irrigation efficiency, domestic and export markets, and crop yields. Production in each ASA was limited by constraints such as environmental quality factors, drainage of wetlands, and maximum rates of change from one crop to another. The Central case projections are based on extrapolation of present trends instead of the linear model.

All of the SCS demand forecasts are based on either OBERS E or OBERS E' economic and population projects. The E' projections are a slight modification of the E projections, which reflect recent changes in per capita consumption of food and fiber, and agricultural exports. Both forecasts assume zero population growth after 2005 with the exception of a small annual increase from immgration.

For each scenario and for each ASA the model predicts the acreage of land for each type of crop and the irrigation demand depending upon the soil class and costs. A summary of agricultural water demand for the major basins is included in Table A-10. Projections are shown for a range of scenarios which indicate the sensitivity of agricultural water demand forecasts to alternative future conditions.

(d) Analysis of Navigation Requirements for Water Flow

Each time a lock cycles, the volume of water released downstream is: $q = L \times W \times l$

Lock operation statistics collected by the Corps of Engineers Performance Monitoring System (PMS), report

Table A-10

Water Demand for Agriculture in the Year 2000
(1000 acre feet per year)

Region	1975	USDA Model Assumptions: Central Case OBERS E	USDA Model Assumptions: Low Export E, LP	USDA Model Assumptions: Moderate Export E'	USDA Model Assumptions: Land Conservation MCC	High Export	Environ. Protection Moderate Export	Energy Developed
Missouri	14,790	16,530	18,030	19,191	19,000	19,369	14,423	18,780
Arkansas	7,244	8,209	8,485	9,562	9,007	9,180	7,039	9,556
Texas Gulf	12,565	9,881	9,382	7,848	7,579	7,786	6,859	7,856
Rio Grande	5,591	4,598	4,897	4,496	4,383	4,653	4,105	4,709
Upper Colo	2,681	2,722	2,766	3,022	3,081	3,025	945	2,729
Lower Colo	5,038	5,173	5,606	5,052	4,608	5,032	5,023	5,038
Great Basin	4,108	4,115	4,215	3,720	3,893	3,810	2,918	3,713
Columbia	15,021	16,331	16,020	17,382	17,017	17,350	9,910	17,438
California	28,012	28,919	27,361	25,340	25,109	25,696	23,766	25,355
Other Regions	3	5	4	3	3	4	4	3
Total - United States	95,053	96,483	96,766	95,616	93,680	95,905	74,992	95,177

"lockages" rather than lock cycles. Each lockage may consist of only the half of a cycle which uses no water, or as many as two full cycles, which consume two chamberfuls of water. The number of lock cycles may be derived from the PMS data because the lockages are broken down by types which are associated with parts of the lock cycle and therefore with water use as shown in Table A-11.

The Lockages must first be divided between upbound and downbound tows. Then the position of the lock in the cycle when the tow arrives must be specified. A fly or exchange lockage is one in which the water level in the lock is already at the level of the arriving tow. Specifically, if a tow enters the lock chamber immediately upon arriving at the approach to the lock, the lockage is recorded as "fly," but when the tow must wait for another vessel bound in the opposite direction to exit the lock, the lockage is recorded as "exchange." This distinction does not affect the consumption of water by the lockage. If the water level in the lock is not at the level of the next tow to be processed, the lockage is called "turnback" and the empty lock must be run halfway through a cycle. Finally, large tows may have to go through the lock in two or more sections or "cuts." More than two "cuts" are rarely required, and the statistics record lockage of more than one cut as double lockages. The water requirement of each of these lockage types is shown in Table III-13.

The water requirements for a given lock can be specified as:

$$Q = q\ [\ T_u + \%D_u \times TNL_u] + q\ [\ TNL_d + q_o D_d \times TNL_d\ ]$$

Where:

Q volume of water demand at a lock per unit time

q chamber volume, L x W x 1

T_u number of turnback lockages of upbound tows per unit time

$\%D_u$ percent of upbound tows which require double lockages

Table A-11

Water Use by Type of Lockage

Type of Lockage	Water Consumption Per Lockage
1. Upbound	
Single:	
fly/exchange	0
turnback	q
Double:	
fly/exchange	q
turnback	2q
2. Downbound	
Single:	
fly/exchange	q
turnback	q
Double:	
fly/exchange	2q
turnback	2q

q = quantity of water to fill lock chamber

$\%D_d$ percent of downbound tows which require double lockages

TNL_u total number of lockages of upbound tows per unit time

TNL_d total number of lockages of downbound tows per unit time

The terms in the first set of brackets express the water demand due to lockages of upbound tows. The term $\%D_u \times TNL_u$ is the number of double lockages of all types. Adding the number of turnback lockages double-counts the number of turnback lockages which are also double lockages. This accounts for the two chamberfuls of water which are required by upbound double turnback lockages. The terms in the second set of brackets similarly double-count the number of downbound double lockages of all types, accounting for their requirement of two lock cycles each.

The terms appearing in the formula above are all available in PMS reports for each month of 1976 and aggregated by the summer months of June, July, and August. There is a potential data problem, as the report values of T_u include only those lockages for which there is good data as selected by the Corps, while TNL_u counts all upbound lockages. It is assumed, however, that the ratio of upbound turnback lockages to the total number of upbound lockages in the remaining data points is unchanged, and thus the number of upound turnback lockages is computed as:

$$T_u^* \quad \frac{T_u}{T_u + F/E_u} \times TNL_u$$

Where T_u^* is the actual number of upbound turnback lockages in the reporting period, T_u is the number of upbound turnback lockages which remain in the PMS reports, and F/E_u is the number of upbound fly and exchange lockages which remain in the PMS reports.

The chamber dimensions and lift of locks were found in the Corps of Engineers Inventory of Inland Waterways and the volume of each lock chamber computed. The peak season average monthly water requirement of each lock was obtained by dividing the number of lockages recorded for three summer months by three, and then adding a margin of five percent in order to account for additional water losses through leakage of the gate seals and seepage through the lock structure.

In the case of locks with two chambers, the water demands of each chamber were computed separately, and the total water demand of the lock is the sum of the demands of the two chambers.

(e) Canalized Segments Analysis

Canalized segments constitute the largest portion of waterway segments evaluated in this task. For these segments, the relationship between water supply and navigation is generally simple and straightforward. There must be enough flow along the waterway to supply the water needed for lockage volumes, leakage through lock and dam structures, and evaporation. The pools behind the dams insure that sufficient channel depths are maintained.

The control point selected for each segment was the lock with the highest water usage requirement. For each case, the water requirement of the controlling lock was compared to the total potential streamflow less the water consumption along and above that segment. A tabular form was completed for each segment which shows the calculations and results of the comparison. A sample is included here as Table A-12.

(f) Free-flowing Segment Analysis

The relationship between navigation and water supply is much more complex on free-flowing segments, as opposed to canalized segments, due to the dynamic nature of an open river. Water requirements are not static as in canalized segments, but are controlled by the hydrologic relationships between river flow and stage.

Table A-12

Flow Assessment - Year 2000
Canalized Segment

SEGMENT

WORST AVERAGE MONTH:
WORST DRY MONTH:

	Scenario				
	Base	Large-Govt	Less-Govt	Bad Energy	Drought
(1) Consumption Along Segment: Average Annual Rate (MGD)					
(2) Consumption Above Segment: Average Annual Rate (MGD)					
(3) Total Consumption: Avg. Annual Rate (MGD) (1) + (2)					
(4) Worst Month Adjustment Factor					
(5) Adjusted Consumption (MGD) (3) x (4)					
(6) Total Stream Flow (MGD)					
(7) Remaining Stream Flow (MGD) (6) - (5)					
(8) Navigation Need (MGD)					
(9) Navigation Need Satisfaction Ratio (7)/(8)					

For each free-flowing segment there is a corresponding design flow and a probability of occurrence for that flow. The relationship between the design flow and the authorized depth and width is controlled by natural factors such as bed load and suspended solids, and man-made factors such as dredging and river training structures. For this analysis it is assumed that all of these factors remain relatively constant. Therefore, any increase in water consumption and its concomitant decrease in streamflow will have an adverse effect upon navigation. The seriousness of this effect depends upon the magnitude of the increase in water consumption as a proportion of the streamflow. If water consumption is doubled from 1000 MGD to 2000 MGD, it will have a much more severe impact on a segment with an average flow of 500 MGD than on a segment with an average flow of 50,000 MGD.

For each free-flowing segment, the increase in total consumption along and above that segment was calculated. The percentage impact upon the drought streamflow (95% probability of exceedance) was computed from this value. The design flow for each segment was then reduced by the forecast reduction in drought streamflow, to calculate future design flow. This calculation assumes that the percent reduction in streamflow in drought conditions (95% probability level) is the same as the percent reduction at the probability level of the design flow which varies normally between 90 and 100%. These calculations were computed in a table for each segment. A sample of the table is included here as Table A-13.

In order to accommodate this reduced flow and still maintain authorized dimensions at the same probability, the maintenance activities would have to be increased. If maintenance levels remain the same, the probability of maintaining design dimensions is reduced. (This relationship is documented in detail in the Element E Report.)

1. Great Lakes Analysis. There are five Great Lakes segments included in this analysis (segment 45 through 49). The navigation-water supply relationships are the most complex in these segments because they share some of the characteristics of locks and dams with pools and some of the characteristics of free flowing rivers. Due to their size, the lakes have relatively constant

Table A-13

Flow Assessment - Year 2000
Free-Flowing Segment

SEGMENT

WORST AVERAGE MONTH:
WORST DRY MONTH:

		Scenario				
		Base	Large-Govt	Less-Govt	Bad Energy	Drought
(1)	Year 2000 Consumption Along Segment: Average Annual Rate (MGD)					
(2)	Year 2000 Consumption Above Segment: Average Annual Rate (MGD)					
(3)	Year 2000 Total Consumption: Avg. Annual Rate (MGD) (1) + (2)					
(4)	Year 2000 Worst Month Adjustment Factor					
(5)	Year 2000 Adjusted Worst Month Consumption (MGD) (3) x (4)					
(6)	Year 1975 Worst Month Consumption (MGD)					
(7)	Years 1975 to 2000 Consumption Increase (MGD) (5) - (6)					

Table A-13 (Cont.)

SEGMENT	WORST AVERAGE MONTH: WORST DRY MONTH:				
	Scenario				
	Base	Large-Govt	Less-Govt	Bad Energy	Drought
(8) Potential Worst Month Streamflow Without Consumption (MGD)					
(9) 1975 Worst Month Net Streamflow (MGD) (8) - (6)					
(10) Year 2000 Worst Month Flow Reduction From 1975 Level (9) - (7)/(9)					

stages over short time periods (excluding storm activity), and require only the water required for lockages between the lakes. This amount of water is a very minor portion of the inflow to the lakes. However, since the lakes are connected by open channels and are not totally regulated by dams long term increases in consumption will cause decreases in lake levels which can impact channel depths in some areas. Thus, the identification of potential water supply problems on the lake segments is based on the difference between existing and future consumption levels and their impact on future lake levels.

(g) Water Demand Disaggreagation

In seven cases where more than one segment flows through a subarea, forecast water consumption demand was disaggregated from NWA subarea totals by using sources from the United States Department of Energy and the United States Department of Commerce. Demand for each segment was estimated by comparing segment data from the subarea incorporating the segment, depending upon the case.

In order to allocate NWA subarea water demand to more than one NWS segment, four categories of water consumption were used. The following assumptions were used to calculate the water demand in each of the four categories:

1. Population was used to allocate domestic commercial, and "other" water consumption.

2. Total employment was used to allocate water consumption for industrial activity.

3. Agricultural earnings were used to allocate irrigation and livestock water consumption.

4. Mining earnings were used to allocate water consumption for mining activity.

The data needed for these calculations were available from United States Water Resources Council and OBERS E' projections.

Power plant cooling consumption was allocated using a DOE document, Inventory of Power Plants in the United States, and backup code data from the Department of Commerce enabling use of the first document. Power plant cooling consumption was allocated on the basis of the ratio of total rated electrical capacity (existing and planned) in the segment against total rated electrical capacity (existing and planned) in the region or subarea used for comparison purposes. This allocation assumes that capacity is utilized equally in areas of comparison. Since the determination of electrical capacity utilization for the year 2000 by region or subarea was not feasible under this task, equivalent capacity utilization is assumed.

The above assumptions for disaggregating water consumptive demand data by segment are only approximate. However, the resulting data is sufficient to identify location where potential flow conflicts with navigation exist.

To generate disaggregated water consumption for the LARGEGOVT, LESSGOVT, and BADENERGY scenarios, the following assumptions were necessary:

1. The "worst month" does not change between original NWA data and the adjusted data.

2. The "worst month water consumption average month water consumption" ration remains constant for each NWA subarea in the future.

3. Water consumption for only a portion of a segment subarea has the same rate of growth as water consumption for the overall subarea.

(h) Corrections to Water Demand Calculations

Two types of corrections were made to raw upstream demand data. First, unsatisfied upstream demand found in drought years was eliminated from total demand on segment flow. Second, the ratios of average demand to worst month

demand for each segment were adjusted for upstream differences.

When the consumptive demand was calculated for some segments it sometimes exceeded the available streamflow during drought periods, particularly segments 10 and 24. In reality a problem like this would be handled by restricting water use or by utilizing longterm storage available in reservoirs. For the present analysis reservoirs are assumed to have been drawn down and storage is not available to significantly supplement streamflow over the long-term. It was therefore assumed that some form of water restrictions would be implemented which would reduce demand. If the calculated demand values were not reduced in this way, it would have the effect on flow calculations of assuming that demand would be satisfied by interbasin transfers of water from downstream. This assumption was considered less realistic than demand management.

The following is a step-by-step demonstration of how NWS Segment 20, the Green River, a portion of NWA Subarea 505, was disaggregated from subarea data to determine water consumption.

STEP 1: Find relevant OBERS Subareas.

The Green River Basin corresponds to OBERS Subarea 515. When combined with OBERS Subarea 511, a section of the Ohio River, the combined area is equivalent to NWA Subarea 505.

STEP 2: Determine allocation for each OBERS Subarea by taking year 2000 numbers in relevant categories and calculating percentages.

	Population (thousands)	Employment (thousands)	Agricultural Earnings (mills of $)	Mining Earnings (mills of $)
OBERS 511	1620	728	95	13
OBERS 515	1282	561	246	204

As percentages:

OBERS 511	56	60	28	6
OBERS 515	44	40	72	94

STEP 3: Pull NWA Subarea data for relevant categories from the G-006 Deliverable and allocate according to the percentages computed in STEP 2.

NWS Subarea 505
Consumption
(MGD):

Domestic and Comm. and "Other"	Indus.	Livestock and Irrigation	Minerals
68	198	80	25

Allocated by STEP 2 Percentages:

OBERS 511 (MGD)	38	119	22	1
OBERS 515 (MGD)	30	79	58	24

STEP 4: Use the Inventory of Power Plants in the United States document to aggregate county data by OBERS Subarea for total rated capacity of existing or planned electrical generating facilities and determine percentage allocations.

Aggregated County Data	Total Rated Capacity (kilowatts)
OBERS 511	10952
OBERS 515	12433

As percentages:

OBERS 511	47
OBERS 515	53

STEP 5: Pull NWA Subarea data for power plant cooling from the G-006 Deliverable and allocate according to the percentages computed in STEP 4.

NWA Subarea 505 consumption: (MGD)	Power Plant Cooling
	171

Allocated by STEP 4 percentages:

OBERS 511 (MGD)	80
OBERS 515 (MGD)	91

STEP 6: Sum the total for the BASE case from the relevant OBERS Subarea as determined in STEPS 3 and 5.

OBERS 515 (Green River Basin):

30 + 79 + 58 + 24 + 91 = 282 MGD

STEP 7: Compute totals for scenarios by computing ratios based on scenario totals for the relevant NWA Subarea from the G-006 Deliverable, and multiplying the NWS Segment BASE case total by the ratios to yield NWS Segment Scenario totals.

Total NWA Subarea 505 Consumption (MGD):

	Base	Large-Govt	Less-Govt	Bad Energy	Drought
	553	544	553	545	562
Divided by NWA Subarea BASE Case MGD (553)	1.000	0.984	1.000	0.986	1.016
Multiplied by NWS Segment BASE Case MGD (282)	282	277	282	278	287

STEP 8: Transfer totals to flow assessment tables.

For example, when forecast demand from the Missouri

basin is greater than streamflow the demand must be reduced. If it is not, it will be included in the estimate of upstream demand for each segment downstream of the Missouri, such as the lower Mississippi River. This total upstream demand would be subtracted from the natural streamflow in the lower Mississippi even though the demand could not be satisfied in the upstream basin. Subtracting this excess upstream demand from the downstream natural flow constitutes an effective transfer of water from the lower Mississippi to the Missouri basin. This is clearly not realistic since no means presently exists to allow this transfer. Therefore, on segments where projected demand exceeds streamflow, that demand is reduced to the level of available streamflow. Table A-14 lists corrections made in consumption forecasts for the year 2000.

Because water demand projections were based on annual average water use rates, they had to be adjusted to worst month consumption rates. An adjustment factor was calculated for each segment. This factor is taken from NWA data and is the ratio of the water consumption rate along and above each segment during the worst month to the annual average rate of water consumption along and above that segment. Use of this factor assumes that this relationship does not change significantly over time and will not vary with changes in total water consumption levels.

The calculation of water demand for the year 2000 and its incorporation into the model assumes that all water is withdrawn from renewable sources and that all ground water mining is ceased. This is a conservative assumption in relation to this analysis since it maximizes the impact of water consumption upon streamflow and, hence, navigation.

The 1975 water consumption levels utilized in the analysis of free flowing segments are from renewable sources only. Consumption from ground water mining is not included in these values. It is also assumed that aquifers which are tapped for ground water mining are hydrologically isolated enough from surface waters so that they have little effect upon streamflow. In order to make a valid evaluation of streamflow changes from 1975 to 2000

Table A-14

Consumption Corrections To Water Deman
Required Because of Excess Upstream Wa

Segment or Segment Grouping	Scenario	Cumulative Adjusted Consumption (MGD)	Water Not Available for Consumptic (MGD)
3	DROUGHT	92,286	(12,034)
4	DROUGHT	93,389	(12,034)
5	BASE	102,465	(4,587)
5	LARGEGOVT	103,921	(4,562)
5	LESSGOVT	100,750	(4,562)
5	BADENERGY	100,223	(4,051)
5	DROUGHT	118,782	(30,578)
6,26	BASE	112,760	(4,587)
6,26	LARGEGOVT	114,192	(4,562)
6,26	LESSGOVT	109,202	(4,562)
6,26	BADENERGY	110,274	(4,051)
6,26	DROUGHT	130,299	(35,840)

resulting from increased consumptive withdrawals, the values of consumption must be those which most directly impact streamflow. Therefore, the estimates for 1975 water consumption include only surface and shallow aquifer water sources while the year 2000 water consumption forecasts include all sources since it is assumed that all ground water mining is halted by that date. This is also a conservative assumption for this analysis as it maximizes the impact of future demand upon surface waters and, hence, navigation.

(i) Water Supply Data

Water supply values used in this analysis were taken from hydrographs prepared for each NWA subarea by the Water Resources Council. The hydrographs are based on the level of water resource development and reservoir management existing in 1975. Reservoir operation was included in the hydrographs to the extent that they affect streamflow, but no special consideration was given to reservoir releases. Calculations of 1975 water consumption were added to the hydrographs to produce estimates of the total potential streamflow. This total potential streamflow is the value used in row (6) of the analysis of canalized segments and row (8) of the analysis for free flowing segments.

Where the NWA subarea boundaries coincided with the NWS segments, the total streamflow data were taken directly from the NWA. This approach was feasible for most segments. For NWA Segments which differed significantly from NWA Subarea boundaries, the NWA flow estimates were adjusted on a unit area basis. This approach was possible on all of the remaining segments except for one.

The NWS Segment group 13, 14, and 15 is contained in NWA Subarea 505 which is downstream from Subarea 502. Subareas 506 and 507 are also tributary to Subarea 505. Because of the special arrangement of the segments and the subareas, it was not possible to accurately calculate the streamflow at the control point for this segment group. Therefore, the flow from ASA 502 was used for this segment group. This is a conservative assumption since it underestimates the flow available in segments 13, 14, and 15.

Although NWA data may not be as detailed as specific hydrologic information which is available for some NWS segments, NWA information was used because it covers all of the segments in a consistent manner. The same set of assumptions supports all NWA hydrographs, eliminating the need for special cases or exceptions in the application of a systematic methodology to analyze the data. For the DROUGHT scenario, the 95% exceedance flow was utilized. The other scenarios used the average annual flow.

(j) Water Supply and Demand Data on Selected Segments

Table A-15 summarizes water supply data in average and dry years for eight selected segments that had detailed analysis of flow. This flow is that measured in 1975 and provided in the NWA statistical appendices. It includes the effects of 1975 development upstream.

Tables A-16 to A-28 provide the water consumption data used in the detailed analysis of the eight segments plus four Great Lakes, which was derived according to the above methodology. This data supports the detailed analysis in Section III of this report.

Table A-15

Monthly Stream Flow Under 1975 Conditions (MGD)
NWS Segment

Month	3. Upper Middle Mississippi		4. Lower Middle Mississippi		10. Missouri River		24. Arkansas River	
	Average	Drought	Average	Drought	Average	Drought	Average	Drought
Jan	76,300	28,200	319,000	113,900	22,600	8,340	23,200	3,260
Feb	92,400	36,100	421,300	149,820	30,600	11,900	28,000	4,750
Mar	142,000	68,700	479,200	254,210	48,700	19,000	31,400	6,580
Apr	204,000	102,000	533,800	313,200	66,000	24,400	43,000	7,330
May	190,000	95,000	434,200	245,680	62,900	25,800	54,800	10,400
Jun	176,000	87,900	336,300	156,700	75,900	28,000	41,100	6,580
Jul	153,000	65,300	265,800	121,120	59,900	21,000	25,100	3,260
Aug	91,800	52,300	178,280	91,140	34,400	16,600	12,900	1,700
Sept	87,300	45,400	136,410	86,000	36,800	15,100	13,000	1,830
Oct	86,600	33,800	134,830	69,180	34,100	12,600	17,700	1,430
Nov	85,300	35,800	159,610	75,780	33,200	12,300	16,500	2,170
Dec	67,900	33,900	223,300	93,200	22,600	9,280	17,800	2,510
Annual	121,000	65,300	302,100	141,970	44,100	17,600	27,000	7,530

SOURCE: NWA Statistical Appendix A-4 (drought = 95% exceedance levels)
3. measured at: St. Louis, Missouri
4. measured at: Memphis, Tennessee
10. measured at: Hermann, Missouri
24. measured at: Little Rock, Arkansas

Table A-15 (Cont.)

Monthly Stream Flow Under 1975 Conditions (MGD)
NWS Segment

Month	25. Red River		25. Ouachita River		36. Alabama River		38. Appalachicola	
	Average	Drought	Average	Drought	Average	Drought	Average	Drought
Jan	17,100	4,460	12,679	120	32,615	9,378	23,711	9,865
Feb	29,400	6,790	15,949	177	41,420	16,412	29,413	13,485
Mar	31,000	8,340	19,051	274	46,161	21,674	35,567	19,910
Apr	30,400	7,630	21,154	317	42,774	15,474	30,318	14,494
May	39,600	9,890	19,051	300	21,517	7,555	18,100	8,661
June	25,900	4,400	14,361	190	11,566	4,950	15,295	8,362
Jul	12,200	2,200	11,321	158	11,514	4,111	15,476	8,190
Aug	6,950	1,360	7,730	118	9,482	3,637	15,476	6,842
Sept	6,080	1,490	5,887	98	7,659	3,298	13,666	6,607
Oct	7,760	1,030	6,275	79	7,450	3,032	12,942	5,149
Nov	9,700	1,420	7,019	80	10,889	3,063	11,041	5,557
Dec	15,700	6,530	7,704	93	20,059	4,986	16,471	6,959

SOURCE: NWA Statistical Appendix A-4 (drought = 95% exceedance levels)

25. (Red) measured at: Alexandria, Louisiana
25. (Ouachita) measured at: Monroe, Louisiana
36. measured at: Claiborn, Alabama
38. measured at: Bloutstown, Florida

Table A-16

Middle Mississippi River
Water Consumption (MGD)

Segment 3

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation Dry	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	1147	563	0	264	1337	14415	16419	820	167	18724	20728
	1980	1191	803	20	292	1666	15234	17393	884	191	20293	22452
	1985	1235	1042	41	320	1995	16053	18367	947	214	21862	24176
	1990	1280	1282	61	358	2324	16873	19342	1011	238	23432	25901
	1995	1324	1521	92	386	2653	17692	20316	1074	261	25001	27625
	2000	1368	1761	102	404	2982	18511	21290	1138	285	26570	29349
Year	2000											
	Jan.	1099	1779	102	404	2982	0	0	911	144	7321	7321
	Feb.	1097	1691	102	404	2982	0	0	933	144	7353	7353
	Mar.	1279	1691	102	404	2982	0	0	979	181	7618	7618
	Apr.	1299	1603	102	404	2982	1481	1703	1013	181	9065	9287
	May	1433	1638	102	404	2982	10366	12135	1195	341	18461	20230
	Jun.	1684	1726	102	404	2982	32579	37470	1343	476	41296	46187
	Jul.	1848	1867	102	404	2982	77376	88992	1480	563	86622	98238
	Aug.	1702	1902	102	404	2982	68306	78560	1480	563	77441	87695
	Sep.	1405	1761	102	404	2982	27581	31722	1298	311	35844	39985
	Oct.	1273	1743	102	404	2982	4443	5110	1059	182	12188	12855
	Nov.	1115	1796	102	404	2982	0	0	956	164	7519	7519
	Dec.	1102	1902	102	404	2982	0	0	911	172	7575	7575
Year	1975											
	Jan.	929	569	0	264	1337	0	0	660	125	3884	3884
	Feb.	927	533	0	264	1337	0	0	679	125	3865	3865
	Mar.	1086	540	0	264	1337	0	0	713	128	4158	4158
	Apr.	1108	516	0	264	1337	450	699	736	128	4539	4788
	May	1208	532	0	264	1337	7684	7813	862	173	12060	12189
	Jun.	1433	560	0	264	1337	27812	37846	965	231	32602	42636
	Jul.	1566	591	0	264	1337	62159	65858	1063	260	67240	70939
	Aug.	1440	620	0	264	1337	50907	59863	1063	258	55889	64845
	Sep.	1193	569	0	264	1337	20151	26700	936	173	24623	31172
	Oct.	1081	563	0	264	1337	3777	5523	763	129	7914	9660
	Nov.	947	566	0	264	1337	15	17	694	125	3948	3950
	Dec.	937	605	0	264	1337	0	0	660	125	3928	3928

SOURCE: Consultants calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-17

Missouri River
Water Consumption (MGD)

Segment 4

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation Dry	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	1191	572	0	267	1366	15745	18000	833	167	20152	22407
	1980	1237	816	20	295	1703	16631	19055	897	191	21803	24227
	1985	1282	1059	41	323	2041	17518	20109	962	215	23455	26046
	1990	1328	1303	61	352	2378	18404	21164	1026	238	25106	29685
	1995	1373	1546	82	380	2716	19291	22218	1091	262	26758	29685
	2000	1419	1790	102	408	3053	20177	23273	1115	286	28409	31505
Year	2000											
	Jan.	1140	1808	102	408	3053	0	0	924	144	7579	7579
	Feb.	1138	1718	102	408	3053	0	0	959	144	7522	7522
	Mar.	1328	1718	102	408	3053	0	0	1005	181	7795	7795
	Apr.	1355	1629	102	408	3053	1614	1862	1040	181	9382	9630
	May	1497	1665	102	408	3053	10290	12102	1213	341	18569	20381
	Jun.	1747	1754	102	408	3053	37933	43986	1363	476	46836	52889
	Jul.	1907	1897	102	408	3053	83936	96816	1502	563	93368	106248
	Aug.	1758	1933	102	408	3053	75260	86576	1502	563	84579	95895
	Sep.	1460	1790	102	408	3053	28651	33048	1317	311	37092	41489
	Oct.	1328	1772	102	408	3053	4439	5120	1074	182	12358	13039
	Nov.	1168	1826	102	408	3053	0	0	959	164	7580	7680
	Dec.	1151	1933	102	408	3053	0	0	924	172	7743	7743
Year	1975											
	Jan.	963	578	0	267	1366	0	0	673	125	3972	3972
	Feb.	961	541	0	267	1366	0	0	692	125	3952	3952
	Mar.	1126	548	0	267	1366	0	0	726	128	4161	4161
	Apr.	1153	524	0	267	1366	450	700	749	128	4637	4887
	May	1260	540	0	267	1366	7727	7879	876	173	12209	12361
	Jun.	1485	570	0	267	1366	31690	43429	979	232	36589	48328
	Jul.	1614	602	0	267	1366	67827	72100	1077	261	73014	77287
	Aug.	1485	631	0	267	1366	56735	66095	1077	259	61820	71180
	Sep.	1238	579	0	267	1366	20697	27549	950	173	25270	32122
	Oct.	1125	572	0	267	1366	3777	5525	776	129	8012	9760
	Nov.	991	575	0	267	1366	15	17	707	125	4046	4048
	Dec.	977	614	0	267	1366	0	0	673	125	4022	4022

SOURCE: Consultants calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-18

Missouri River
Water Consumption (MGD)

Segment 10

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation Dry	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	331	68	0	111	134	14214	16168	450	159	15467	17421
	1980	341	145	17	121	148	14991	17090	492	180	16435	18534
	1985	351	221	35	132	161	15768	18011	533	202	17403	19646
	1990	361	298	52	142	175	16545	18933	575	223	18370	20758
	1995	370	374	70	153	188	17322	19854	616	245	19338	21870
	2000	380	451	87	163	202	18099	20776	658	266	20306	22983
Year	2000											
	Jan.	228	428	87	163	202	0	0	458	142	1708	1708
	Feb.	231	410	87	163	202	0	0	484	142	1719	1719
	Mar.	325	406	87	163	202	0	0	530	176	1889	1889
	Apr.	331	388	87	163	202	1629	1662	562	176	3538	3571
	May	392	397	87	163	202	10135	11842	708	318	12402	14109
	Jun.	604	446	87	163	202	31492	36358	831	430	34255	39121
	Jul.	627	541	87	163	202	75654	86636	963	505	78742	89724
	Aug.	609	546	87	163	202	66785	76663	963	504	69859	79737
	Sep.	410	451	87	163	202	26968	31164	811	288	29380	33576
	Oct.	310	437	87	163	202	4525	4986	603	177	6504	6965
	Nov.	239	465	87	163	202	0	0	505	162	1823	1823
	Dec.	228	487	87	163	202	0	0	458	171	1796	1796
Year	1975											
	Jan.	197	66	0	111	134	0	0	310	125	943	943
	Feb.	200	63	0	111	134	0	0	329	125	962	962
	Mar.	284	63	0	111	134	0	0	362	128	1082	1082
	Apr.	288	60	0	111	134	450	699	384	128	1555	1804
	May	340	61	0	111	134	7658	7711	485	165	8954	9007
	Jun.	524	69	0	111	134	27381	37267	566	215	29000	38886
	Jul.	543	78	0	111	134	61248	64779	661	241	63016	66547
	Aug.	524	81	0	111	134	50100	58923	661	239	51850	60673
	Sep.	354	70	0	111	134	19953	26414	556	165	21323	27804
	Oct.	270	67	0	111	134	3777	5519	911	129	4899	6641
	Nov.	208	70	0	111	134	15	17	344	125	1007	1009
	Dec.	197	72	0	111	134	0	0	310	125	949	949

SOURCE: Consultants calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-19

Arkansas River
Water Consumption (MGD)

Segment 24

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation Dry	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	229	64	0	109	119	4825	5719	142	25	5513	6407
	1980	235	80	1	116	145	4813	5696	151	27	5568	6451
	1985	241	96	3	122	171	4801	5673	159	29	5622	6494
	1990	248	111	4	129	196	4788	5651	168	30	5674	6537
	1995	255	127	6	135	222	4776	5628	176	32	5729	6581
	2000	260	143	7	142	248	4764	5605	185	34	5783	6624
Year	2000											
	Jan.	156	136	7	142	248	191	224	141	23	1044	1077
	Feb.	160	113	7	142	248	238	280	149	23	1080	1122
	Mar.	224	114	7	142	248	429	504	155	24	1343	1385
	Apr.	229	117	7	142	248	762	897	170	24	1699	1834
	May	268	137	7	142	248	2668	3139	193	36	3699	4170
	Jun.	417	169	7	142	248	6050	7399	229	50	7312	8661
	Jul.	431	180	7	142	248	21486	25279	250	58	22802	26595
	Aug.	417	180	7	142	248	19771	22981	243	58	21066	24276
Year	1975											
	Jan.	131	60	0	109	119	308	370	109	21	857	919
	Feb.	141	52	0	109	119	333	354	113	21	888	949
	Mar.	198	52	0	109	119	764	937	119	22	1383	1556
	Apr.	200	52	0	109	119	2061	2486	129	23	2693	3118
	May	237	57	0	109	119	5021	5938	146	27	5716	6633
	Jun.	370	72	0	109	119	7774	9229	175	32	8651	10106
	Jul.	382	86	0	109	119	16521	19051	192	33	17442	19972
	Aug.	370	86	0	109	119	15999	18840	186	30	16899	19740
	Sep.	248	74	0	109	119	6400	8081	163	24	7137	8818
	Oct.	190	61	0	109	119	1771	2008	135	21	2406	2643
	Nov.	148	56	0	109	119	642	825	119	21	1214	1397
	Dec.	137	61	0	109	119	308	370	109	21	864	926

SOURCE: Consultants calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-20

Red River
Water Consumption (MGD)

Segme.

		estic nercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation Dry	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	103	25	0	61	45	2161	2429	60	0	2454	2722
	1980	104	36	0	63	58	2115	2377	64	0	2440	2702
	1985	105	47	0	65	70	2069	2273	68	0	2424	2680
	1990	106	57	0	66	83	2024	2073	71	1	2408	2657
	1995	107	68	0	68	95	1978	2221	75	1	2392	2635
	2000	108	79	0	70	108	1932	2169	79	1	2377	2614
Year	2000											
	Jan.	64	76	0	70	108	19	30	62	0	399	410
	Feb.	66	62	0	70	108	39	51	64	0	409	421
	Mar.	93	62	0	70	108	116	132	66	0	515	531
	Apr.	95	64	0	70	108	599	674	72	0	1008	1083
	May	111	76	0	70	108	2260	2547	82	1	2708	2995
	Jun.	174	87	0	70	108	4096	4601	96	3	4634	5139
	Jul.	179	108	0	70	108	6260	7019	105	3	6833	7592
	Aug.	174	111	0	70	108	5545	6239	102	3	6113	6807
	Sept	117	87	0	70	108	3536	3962	90	1	4009	4435
	Oct.	89	76	0	70	108	618	691	75	0	1036	1109
	Nov.	69	64	0	70	108	58	71	66	0	435	448
	Dec.	64	76	0	70	108	9	10	62	0	389	390
Year	1975											
	Jan.	61	21	0	61	45	204	236	47	0	439	471
	Feb.	64	17	0	61	45	589	643	48	0	824	878
	Mar.	88	17	0	61	45	1436	1586	51	0	1698	1848
	Apr.	88	19	0	61	45	1908	2157	54	0	2175	2424
	May	106	24	0	61	45	2250	2675	62	1	2549	2974
	Jun.	163	29	0	61	45	2872	3331	73	1	3244	3703
	Jul.	170	36	0	61	45	5958	6684	79	1	6350	7076
	Aug.	163	36	0	61	45	6580	7244	77	1	6963	7627
	Sep.	110	31	0	61	45	3180	3663	68	1	3496	3979
	Oct.	84	24	0	61	45	461	557	57	0	732	828
	Nov.	66	21	0	61	45	386	450	50	0	629	693
	Dec.	61	24	0	61	45	107	118	47	0	345	356

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-21

Ouachita River
Water Consumption (MGD)

Segment 25

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation Dry	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	44	5	0	7	37	280	319	3	0	376	405
	1980	45	13	0	8	61	283	322	3	0	413	452
	1985	46	21	0	9	85	286	326	3	0	451	491
	1990	47	29	0	10	110	289	329	4	0	488	528
	1995	48	37	0	11	134	292	333	4	0	524	567
	2000	49	45	0	12	158	295	336	4	0	563	604
Year	2000											
	Jan.	38	43	0	12	158	0	0	4	0	255	255
	Feb.	38	37	0	12	158	0	0	4	0	249	249
	Mar.	45	37	0	12	158	0	0	4	0	256	256
	Apr.	51	37	0	12	158	45	54	4	0	306	314
	May	58	43	0	12	158	427	487	4	0	702	762
	Jun.	57	54	0	12	158	765	871	4	0	1050	1156
	Jul.	53	59	0	12	158	1136	1294	4	0	1415	1573
	Aug.	51	54	0	12	158	1061	1208	4	0	1340	1487
	Sept	51	48	0	12	158	105	120	4	0	378	393
	Oct.	50	43	0	12	158	0	0	4	0	267	267
	Nov.	48	43	0	12	158	0	0	4	0	265	265
	Dec.	45	43	0	12	158	0	0	4	0	262	262
Year	1975											
	Jan.	34	5	0	7	37	0	0	3	0	86	86
	Feb.	34	4	0	7	37	0	0	3	0	85	85
	Mar.	41	4	0	7	37	0	0	3	0	92	92
	Apr.	46	4	0	7	37	48	63	3	0	143	158
	May	52	5	0	7	37	420	459	3	0	522	561
	Jun.	52	6	0	7	37	738	904	3	0	843	1009
	Jul.	48	6	0	7	37	1082	1203	3	0	1193	1314
	Aug.	46	6	0	7	37	996	1092	3	0	1092	1188
	Sep.	46	5	0	7	37	75	107	3	0	173	205
	Oct.	45	5	0	7	37	0	0	3	0	97	97
	Nov.	44	5	0	7	37	0	0	3	0	96	96
	Dec.	41	5	0	7	37	0	0	3	0	93	93

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A 22

Alabama-Coosa River
Water Consumption (MGD)

Segment 36

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation Dry	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	45	23	0	7	39	3	4	7	0	124	125
	1980	47	41	0	8	72	3	4	8	0	180	181
	1985	49	60	0	8	106	3	4	9	0	236	237
	1990	51	78	0	9	139	4	5	11	0	291	292
	1995	53	97	0	9	173	4	5	12	0	347	348
	2000	55	115	0	10	206	4	5	13	0	403	404
Year	2000											
	Jan.	47	105	0	10	206	0	0	13	0	381	381
	Feb.	45	97	0	10	206	0	0	13	0	371	371
	Mar.	49	100	0	10	206	0	0	13	0	378	378
	Apr.	55	98	0	10	206	1	1	13	0	383	383
	May	58	108	0	10	206	11	14	14	0	407	410
	Jun.	57	125	0	10	206	15	20	14	0	427	432
	Jul.	53	138	0	10	206	10	13	14	0	431	434
	Aug.	56	145	0	10	206	9	12	14	0	440	443
	Sept	56	131	0	10	206	1	2	14	0	418	419
	Oct.	57	117	0	10	206	0	0	13	0	403	403
	Nov.	56	107	0	10	206	0	0	13	0	392	392
	Dec.	55	109	0	10	206	0	0	13	0	393	393
Year	1975											
	Jan.	39	21	0	7	39	0	0	7	0	113	113
	Feb.	38	18	0	7	39	0	0	7	0	109	109
	Mar.	41	19	0	7	39	0	0	7	0	113	113
	Apr.	47	19	0	7	39	0	2	7	0	121	121
	May	49	21	0	7	39	8	13	7	0	127	129
	Jun.	49	26	0	7	39	11	16	7	0	139	144
	Jul.	46	29	0	7	39	8	10	7	0	136	138
	Aug.	48	29	0	7	39	8	10	7	0	138	140
	Sep.	47	27	0	7	39	2	2	7	0	129	129
	Oct.	50	24	0	7	39	0	0	7	0	127	127
	Nov.	47	22	0	7	39	0	0	7	0	122	122
	Dec.	46	22	0	7	39	0	0	7	0	121	121

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-23

Apalachicola-Chattahoochee-Flint Rivers
Water Consumption (MGD)

Segment 38

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation (Dry)	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	56	12	0	6	52	89	107	14	1	230	248
	1980	60	27	0	7	73	106	127	16	1	290	311
	1985	63	43	0	8	94	123	148	18	1	350	375
	1990	67	58	0	9	115	140	168	19	2	410	438
	1995	70	74	0	10	136	157	189	21	2	470	502
	2000	74	89	0	11	157	174	209	23	2	530	555
Year	2000											
	Jan.	68	81	0	11	157	10	14	22	0	349	353
	Feb.	63	75	0	11	157	7	11	22	0	335	339
	Mar.	77	77	0	11	157	24	32	22	1	377	385
	Apr.	83	76	0	11	157	66	105	22	1	416	455
	May	96	84	0	11	157	294	366	23	3	668	740
	Jun.	96	97	0	11	157	609	704	25	5	1000	1095
	Jul.	93	107	0	11	157	587	682	25	6	986	1081
	Aug.	87	112	0	11	157	342	397	25	6	740	795
	Sep.	83	102	0	11	157	69	92	23	3	448	471
	Oct.	84	91	0	11	157	35	49	22	1	401	415
	Nov.	75	83	0	11	157	31	38	22	0	379	386
	Dec.	71	85	0	11	157	14	18	22	0	360	364
Year	1975											
	Jan.	47	11	0	6	52	7	11	14	0	137	141
	Feb.	43	10	0	6	52	7	7	14	0	132	132
	Mar.	53	10	0	6	52	18	21	14	0	153	156
	Apr.	57	10	0	6	52	39	39	14	0	178	203
	May	66	11	0	6	52	150	182	15	1	301	333
	Jun.	65	13	0	6	52	296	344	16	2	450	498
	Jul.	63	15	0	6	52	289	333	16	2	442	486
	Aug.	61	15	0	6	52	171	200	16	2	322	351
	Sep.	56	14	0	6	52	36	46	15	1	180	190
	Oct.	57	12	0	6	52	25	32	14	0	167	174
	Nov.	52	11	0	6	52	21	29	14	0	156	164
	Dec.	49	11	0	6	52	11	14	14	0	142	146

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-24

Lake Ontario
Water Consumption (MGD)

Segment 45

		Domestic Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation (Dry)	Live-Stock	Other	Total Ave. Year	Total Dry Year
Year	1975	56	13	0	8	20	7	9	14	0	119	121
	1980	58	25	0	9	31	8	10	14	0	146	148
	1985	60	37	0	10	42	9	12	14	0	174	177
	1990	62	50	0	12	53	10	13	15	0	201	204
	1995	64	62	0	13	64	11	15	15	0	229	233
	2000	66	74	0	14	75	12	16	15	0	256	260
Year	2000											
	Jan.	65	84	0	14	75	0	0	15	0	253	253
	Feb.	62	84	0	14	75	0	0	15	0	250	250
	Mar.	67	76	0	14	75	0	0	15	0	247	247
	Apr.	66	58	0	14	75	0	0	15	0	228	228
	May	70	58	0	14	75	0	0	16	0	233	233
	Jun.	70	62	0	14	75	11	25	16	0	248	262
	Jul.	73	71	0	14	75	73	90	16	0	322	339
	Aug.	73	80	0	14	75	59	77	16	0	317	335
	Sep.	63	71	0	14	75	1	2	16	0	240	241
	Oct.	63	80	0	14	75	0	0	15	0	247	247
	Nov.	60	76	0	14	75	0	0	15	0	240	240
	Dec.	61	89	0	14	75	0	0	15	0	254	254
Year	1975											
	Jan.	55	14	0	8	20	0	0	13	0	111	111
	Feb.	52	16	0	8	20	0	0	13	0	110	110
	Mar.	58	13	0	8	20	0	0	13	0	112	112
	Apr.	57	10	0	8	20	0	0	13	0	108	108
	May	60	10	0	8	20	0	0	14	0	113	113
	Jun.	60	11	0	8	20	6	13	15	0	120	127
	Jul.	63	12	0	8	20	44	54	15	0	162	172
	Aug.	62	14	0	8	20	35	46	15	0	154	166
	Sep.	55	12	0	8	20	0	0	14	0	110	110
	Oct.	55	14	0	8	20	0	0	13	0	111	111
	Nov.	50	13	0	8	20	0	0	13	0	106	106
	Dec.	52	16	0	8	20	0	0	13	0	109	109

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-25

Lake Erie
Water Consumption (MGD)

Segment 46

		Domestic & Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation (Dry)	Live-stock	Other	Total Ave. Year	Total Dry Year
Year	1975	300	9	0	29	899	17	21	19	0	1321	1325
	1980	303	48	0	33	896	29	24	19	0	1357	1361
	1985	306	116	0	37	893	23	28	19	0	1393	1398
	1990	310	145	0	40	890	26	31	18	0	1428	1433
	1995	313	173	0	44	887	29	35	18	0	1464	1470
	2000	316	202	0	48	884	32	38	18	0	1500	1506
Year	2000											
	Jan.	312	214	0	48	884	0	0	18	0	1476	1476
	Feb.	282	199	0	48	884	0	0	18	0	1431	1431
	Mar.	314	202	0	48	884	0	0	18	0	1466	1466
	Apr.	312	190	0	48	884	0	0	18	0	1452	1452
	May	301	190	0	48	884	9	13	18	0	1450	1454
	Jun.	330	190	0	48	884	68	89	20	0	1540	1561
	Jul.	431	195	0	48	884	151	177	20	0	1729	1755
	Aug.	367	206	0	48	884	115	138	20	0	1640	1663
	Sep.	304	201	0	48	884	35	41	18	0	1490	1496
	Oct.	293	207	0	48	884	0	0	18	0	1450	1450
	Nov.	270	217	0	48	884	0	0	18	0	1437	1437
	Dec.	273	215	0	48	884	0	0	18	0	1438	1438
Year	1975											
	Jan.	296	63	0	29	899	0	0	18	0	1304	1304
	Feb.	269	56	0	29	899	0	0	18	0	1269	1269
	Mar.	297	59	0	29	899	0	0	18	0	1302	1302
	[illegible]	[illegible]	[illegible]	0	29	899	0	0	18	[illegible]	1297	1297

Table A-26

Lake Huron
Water Consumption (MGD)

Segment 47

		Domestic & Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation (Dry)	Live-stock	Other	Total Ave. Year	Total Dry Year
Year	1975	28	12	0	11	15	8	9	6	0	80	81
	1980	29	14	0	12	31	10	11	6	0	105	107
	1985	30	16	0	13	47	11	13	6	0	130	132
	1990	31	18	0	15	62	13	15	6	1	156	158
	1995	32	20	0	16	78	14	17	6	1	181	184
	2000	33	22	0	17	93	16	19	6	1	206	209
Year	2000											
	Jan.	29	23	0	17	93	0	0	5	0	167	167
	Feb.	30	21	0	17	93	0	0	5	0	166	166
	Mar.	33	22	0	17	93	0	0	5	0	170	170
	Apr.	35	21	0	17	93	0	0	5	0	171	171
	May	36	21	0	17	93	1	3	6	2	176	178
	Jun.	37	21	0	17	93	27	33	6	3	204	210
	Jul.	39	21	0	17	93	73	85	6	4	253	265
	Aug.	36	22	0	17	93	74	85	6	4	252	263
	Sep.	32	21	0	17	93	17	27	6	2	188	200
	Oct.	35	22	0	17	93	0	0	5	0	172	172
	Nov.	28	23	0	17	93	0	0	5	0	166	166
	Dec.	28	24	0	17	93	0	0	5	0	167	167
Year	1975											
	Jan.	24	13	0	11	15	0	0	5	0	69	69
	Feb.	25	11	0	11	15	0	0	5	0	68	68
	Mar.	27	12	0	11	15	0	0	5	0	72	72
	Apr.	29	11	0	11	15	0	0	5	0	72	72
	May	29	12	0	11	15	0	1	6	0	74	75
	Jun.	32	12	0	11	15	13	16	6	1	89	93
	Jul.	34	12	0	11	15	36	41	6	1	114	119
	Aug.	31	12	0	11	15	37	41	6	1	112	116
	Sep.	27	12	0	11	15	9	13	6	1	80	84
	Oct.	26	12	0	11	15	0	0	5	0	70	70
	Nov.	23	12	0	11	15	0	0	5	0	67	67
	Dec.	23	13	0	11	15	0	0	5	0	68	68

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-27

Lake Michigan
Water Consumption (MGD)

Segment 48

		Domestic & Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation (Dry)	Live-stock	Other	Total Ave. Year	Total Dry Year
Year	1975	196	88	0	23	506	82	98	44	2	940	956
	1980	197	106	0	25	594	100	119	44	3	1067	1086
	1985	198	124	0	27	682	117	141	45	3	1194	1218
	1990	198	141	0	28	769	135	162	45	4	1321	1348
	1995	199	159	0	30	857	152	184	46	4	1448	1490
	2000	200	177	0	32	945	170	205	46	5	1575	1610
Year	2000											
	Jan.	179	180	0	32	945	0	0	44	1	1381	1381
	Feb.	174	169	0	32	945	0	0	44	1	1367	1367
	Mar.	195	179	0	32	945	0	0	44	2	1399	1399
	Apr.	196	167	0	32	945	0	0	44	2	1388	1388
	May	209	171	0	32	945	75	122	47	7	1488	1535
	Jun.	221	177	0	32	945	329	428	49	13	1769	1867
	Jul.	240	179	0	32	945	750	855	49	16	2213	2318
	Aug.	219	185	0	32	945	647	743	49	16	2095	2191
	Sep.	207	176	0	32	945	237	306	47	7	1653	1722
	Oct.	199	180	0	32	945	0	12	44	2	1416	1416
	Nov.	173	180	0	32	945	0	0	44	1	1377	1377
	Dec.	173	180	0	32	945	0	0	44	1	1377	1377
Year	1975											
	Jan.	175	92	0	23	506	0	0	42	0	840	840
	Feb.	173	83	0	23	506	0	0	42	0	828	828
	Mar.	192	88	0	23	506	0	0	42	0	855	855
	Apr.	195	83	0	23	506	0	0	42	0	848	848
	May	206	84	0	23	506	32	53	44	2	899	920
	Jun.	227	86	0	23	506	155	202	47	5	978	1025
	Jul.	243	89	0	23	506	360	411	47	5	1266	1317
	Aug.	215	91	0	23	506	314	360	47	5	1203	1249
	Sep.	202	86	0	23	506	114	149	44	2	978	1013
	Oct.	194	88	0	23	506	0	5	42	0	854	859
	Nov.	169	89	0	23	506	0	0	42	0	830	830
	Dec.	168	95	0	23	506	0	0	42	0	837	837

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Table A-28

Lake Superior
Water Consumption (MGD)

Segment 49

		Domestic & Commercial	Power Plant Cooling	Synthetic Fuels	Minerals	Industrial	Irrigation (Ave.)	Irrigation (Dry)	Live-stock	Other	Total Ave. Year	Total Dry Year
Year	1975	9	3	0	82	32	0	0	2	4	133	133
	1980	9	6	0	86	37	0	0	2	5	146	146
	1985	9	9	0	89	43	0	0	2	7	159	159
	1990	8	12	0	93	48	0	1	2	8	172	173
	1995	8	15	0	96	54	0	1	2	10	185	186
	2000	8	18	0	100	59	0	1	2	11	198	199
Year	2000											
	Jan.	8	19	0	100	59	0	0	2	2	190	190
	Feb.	8	17	0	100	59	0	0	2	2	188	188
	Mar.	9	18	0	100	59	0	0	2	3	191	191
	Apr.	9	17	0	100	59	0	0	2	3	190	190
	May	11	17	0	100	59	0	0	2	13	202	202
	Jun.	11	17	0	100	59	0	2	2	26	215	217
	Jul.	11	19	0	100	59	2	5	2	32	225	228
	Aug.	9	19	0	100	59	2	2	2	32	223	223
	Sep.	8	17	0	100	59	0	0	2	13	189	189
	Oct.	8	18	0	100	59	0	0	2	3	190	190
	Nov.	8	18	0	100	59	0	0	2	2	189	189
	Dec.	8	20	0	100	59	0	0	2	2	191	191
Year	1975											
	Jan.	9	3	0	82	32	0	0	2	1	128	128
	Feb.	9	3	0	82	32	0	0	2	1	128	128
	Mar.	9	3	0	82	32	0	0	2	1	130	130
	Apr.	10	3	0	82	32	0	0	2	1	130	130
	May	11	3	0	82	32	0	0	2	5	134	134
	Jun.	12	3	0	82	32	0	0	2	9	139	139
	Jul.	11	3	0	82	32	1	1	2	12	143	143
	Aug.	9	3	0	82	32	1	1	2	12	142	142
	Sep.	9	3	0	82	32	0	0	2	5	133	133
	Oct.	9	3	0	82	32	0	0	2	1	129	129
	Nov.	7	3	0	82	32	0	0	2	1	127	127
	Dec.	7	3	0	82	32	0	0	2	1	128	128

SOURCE: Consultant's calculations, based on NWA data, modified by NWS macro-economic forecasts.

Exhibit A-1

Sample Analysis Sheet for NWA Data
(Demand in MGD)

	Domes. and Commer.	Energy Cool.	Energy Mining	Minerals	Industrial	Agriculture Irrigation avg.\dry	Agriculture Livst. avg.\dry	Other
J	407	86	10	107	209	1096/1388	13	0
F	391	80	10	107	209	1318/1921	13	0
M	453	85	10	107	209	2035/2816	13	0
A	451	86	10	107	209	3207/4145	13	0
M	337	96	10	107	209	4114/4847	14	0
J	397	108	10	107	209	1970/2744	15	0
J	412	117	10	107	209	2510/85	15	0
A	419	123	10	107	209	2803/3754	15	0
S	399	117	10	107	209	1479/2013	14	0
O	402	107	10	107	209	2458/3104	13	0
N	402	91	10	107	209	2531/3068	13	0
D	405	92	10	107	209	1585/2074	13	0
Annual	414	99	10	107	209	2259/2930	14	0

APPENDIX B

DETAILED METHODOLOGY FOR THE RECREATION ANALYSIS

DETAILED METHODOLOGY FOR THE RECREATION ANALYSIS

This appendix provides information on the basic data sources for the analysis of recreation-navigation interactions and the detailed forecasting methodology for recreation use. The results of this analysis for the national waterways is contained in Section VI of this report.

DATA ON RECREATIONAL USE OF THE COMMERCIAL WATERWAY SYSTEM

Two basic sources of data concerning recreational use of Corps facilities were used for this study. The first is the Corps' Recreational Resources Management System (RRMS), which covers identified Corps facilities both on and off the commercial waterways system. The second is the NWS Inventory, which contains data reported by Corps districts for the segments and subsequents identified as commercial waterways for the NWS study. While there is considerable overlap between the two data sets, they are not perfectly congruent and they often report somewhat dissimilar data. The available recreational use data are described below and summarized in Table B-1.

(a) Recreational Resources Management System (RRMs) Data

The Corps maintains over 440 projects having an annual visitation of over 5,000 recreational user days. Visitation data are recorded annually by the project managers and entered into the Corps' Recreational Resource Management System. Data for 1977 are given in the Corps publication, 1977 Recreation Statistics, GOP, June, 1978.

Table B-1

Recreation Data on the Waterway System

Available from Corps Sources

	Segment	User Days (RRMS)	User Days (NWS)	Ports	Locks
1.	Upper Mississippi River	25,051,400	46,279,296	4	25
2.	Lower Upper Mississippi River	5,832,200	-	-	3
3.	Middle Mississippi River	-	-	-	2
4.	Lower Middle Mississippi River	-	-	-	-
5.	Upper Lower Mississippi River	-	-	-	-
6.	Lower Mississippi River - Old River to Baton Rouge, La.	-	-	-	-
7.	Mississippi River - Baton Rouge, La. to New Orleans, La.	-	-	-	-
8.	Mississippi River - New Orleans, La. to Gulf	-	-	-	-
9.	Illinois Waterway	11,800	2,000,000	-	9
10.	Missouri River	4,212,500	9,477,712	-	-
11.	Upper Ohio River	1,194,200	550,200	-	9
12.	Middle Ohio River	2,136,437	204,600	2	4
13.	Lower Ohio River - Three		204,600	-	3
14.	Lower Ohio River - Two	296,742	204,600	1	3
15.	Lower Ohio River - One		-	-	2
16.	Monongahela River	1,210,300	370,300	-	9
17.	Allegheny River	348,400	348,300	-	8
18.	Kanawha River	58,000	-		3
19.	Kentucky River	183,921	78,800	-	14
20.	Green River	60,940	225,100	-	3
21.	Cumberland River	13,996,200	13,139,000	1	4

Table B-1 (Cont'd.)

	Segment	User Days (RRMS)	User Days (NWS)	Ports	Locks
22.	Upper Tennessee River and Clinch River	-	42,185,800	2	8
23.	Lower Tennessee River to Ohio River	-	6,623,200	-	2
24.	Arkansas, Verdigris, White and Black Rivers	14,906,600	20,593,500	-	17
25.	Ouachita-Black and Red Rivers	2,189,200	1,865,010	1	5
26.	Old and Atchafalaya River, Mississippi River to Gulf	-	-	-	1
27.	Baton Rouge, La. - Morgan City, La. Bypass	-	-	-	1
28.	GIWW West One (and tributaries)	-	-	4	3
29.	GIWW West Two (and tributaries)	-	-	7	6
30.	GIWW West Three (and tributaries)	-	-	3	-
31.	GIWW East One (and tributaries)	643,500	410,360	3	4
32.	GIWW East Two	-	-	5	-
33.	Florida Gulf Coast	2,752,114	-	3	4
34.	Houston Ship Canal	-	-	3	-
35.	Black Warrior and Tombigbee River	4,511,700	4,087,100	1	4
36.	Alabama Coosa River	4,162,700	2,647,500	1	5
37.	Tennessee-Tombigbee Waterway	-	-	-	(2)
38.	Apalachicola, Chattahoochee, Flint Rivers	22,103,514	7,192,060	1	3
39.	Florida/Georgia Coast	217,200	-	3	1
40.	Carolinas Coast	224,500	154,585	3	3
41.	Chesapeake and Delaware Bays	341,477	340,724	11	3
42.	New Jersey/New York Coast	-	22,313,000	24	-
43.	New York State Waterways	-	-	5	60
44.	Upper Atlantic	1,924,012	314,420	19	-

Table B-1 (Cont'd.)

	Segment	User Days (RRMS)	User Days (NWS)	Ports	Locks
45.	Lake Ontario and St. Lawrence Seaway	-	-	19	-
46.	Lake Erie	-	33,371,000	7	8
47.	Lake Huron	945,500	32,699,000	16	4
48.	Lake Michigan	28,500	25,924,000	24	-
49.	Lake Superior	1,067,600	1,288,407	5	-
50.	Puget Sound	1,324,500	862,353	9	1
51.	Upper Columbia-Snake Waterway	8,217,500	1,973,542	3	8
52.	Lower Columbia-Snake Waterway/ Willamette River	-	-	8	1
53.	Oregon/Washington Coast	-	1,303,948	3	-
54.	Northern California	-	47,300	2	-
55.	San Francisco Bay Area	-	400,500	8	5
56.	Central/South California	-	-	4	-
57.	Southeast Alaska	-	-	4	-
58.	South Central Alaska Coast	-	-	5	-
59.	West and North Coasts of Alaska	-	-	1	-
60.	Western Pacific, including Hawaii, Guam and American Samoa	-	-	2	-
61.	Caribbean, including Puerto Rico and Virgin Islands	-	-	-	-

Table B-1: DEFINITION OF TERMS

1. User days (RRMS): Segment totals are derived by adding up the total number of user days recorded in the RRMS 1977 Recreation for each Corps facility located on each segment.

2. User days (NWS): Segment totals are derived by adding up data for subsegments entered into the NWS Inventory by Corps planners. The data are supposed to represent an average for the past three to five years. A wide variety of sources was used by Corps planners in establishing these subsegment totals.

3. Ports: Number of commercial ports listed in the NWS Inventory (annual volume over 250,000 tons) reported as containing recreational facilities (marinas, mooring ships, or launching ramps).

4. Locks: Number of locks on the segment reporting recreational craft usage in the NWS Inventory.

Recreational use of Corps projects has been increasing over the first ten years at a global rate of eight percent per year. About two-thirds of such projects are located within 50 miles of an SMSA. Participation by recreational activity can be summarized as follows:

- 16 percent picnicking.
- 11 percent camping.
- 10 percent swimming.
- 4 percent water skiing.
- 18 percent boating.
- 34 percent sightseeing.
- 26 percent fishing.
- 6 percent other

The projects on the commercial waterways system having the highest recreational use (over 500,000 user-days) include:

1. Mississippi River Pools 4, 6, 11-19, 21, 22, 24, 25, and 26.

2. Greenup and Meldahl L/Ds on the Upper Ohio.

3. Locks and dams on the Cumberland River.

4. David Terry, Murray, Toad Suck Ferry, Ozark Lake, Dardanelle, and L/D No. 13 on the Arkansas.

5. Robert Kerr, Webbers Falls and Newt Graham Locks on Verdigris.

6. Jonesville and Columbia L/Ds on the Ouachita.

7. Okeechobee Waterway.

8. Black, Warrior and Tombigbee Locks and Dams.

9. Clairborne L/D, Millers Ferry L/D (Dannelly Reservoir) and Jones Bluff L/D on the Alabama Coosa.

10. Walter F. George L/D, Jim Woodruff L/D and Lake Seminole on the Chattahoochee.

11. Cape Cod Canal.

12. St. Mary's River between Lake Huron and Lake Superior.

13. Duluth Ship Canal on Lake Superior.

14. Lake Washington Ship Canal on Puget Sound.

15. Bonneville L/D and Lake. John Day L/D (Lake Umatilla), McNary L/D (Lake Wallula), and Lower Granite L/D on the Columbia.

In addition, high recreation use is registered on the four reservoirs providing water releases for navigation purposes:

1. Louis and Clark Lake (Gavins Point Dam) on the Missouri.

2. Oolagah Lake on the Verdigris.

3. Buford Dam (Lake Sidney Lanier) on the Chattahoochee.

4. Tygart Lake on the Monongahela.

These are the only reservoirs for which navigation releases by themselves are authorized. Gavins Point is part of a system of reservoirs on the upper Missouri. Navigation releases are authorized for the system as a whole but have the lowest priority among authorized uses. In practice, navigation releases are made only from Gavins Point.

(b) Recreational Use Data from the NWS Inventory

Recreational use data are given in the NWS Inventory for parts of 24 out of the 61 analytic segments. It appears from the Inventory that the heaviest recreation

use is experienced on the Upper Mississippi, followed by the Tennessee River and the beaches of the Great Lakes, particularly Lakes Erie, Huron, and Michigan. The New Jersey/New York Coast, the Arkansas Verdigris system, and the Cumberland River are also important generators of recreational activity, according to the NWS Inventory data. Lesser amounts of recreation use (over 1 million user-days per year) are reported for Lake Superior, the Missouri River, the ACF group, the Black Warrior, the Alabama-Coosa, the Illinois Waterway, the Upper Columbia/ Snake Waterway, the Ouachita, Black and Red group, and the Oregon/Washington Coast.

(c) Data on Recreational Use of Locks and Dams

There are 42 segments with locks and 19 segments without locks. The NWS Inventory describes the annual number of recreational craft passing through each lock. Those locks on the commercial waterways system having a high number of recreational craft passing through each year (defined as over 3,650 or an average of more than 10 per day) include:

1. L/D No. 11 through 15 on the Upper Mississippi.

2. T.J. O'Brien on the Illinois Waterway.

3. Locks No. 2 through 4 on the Allegheny River.

4. Lock No. 1 on the Kentucky River*.

5. Guntersville and Chickamauga on the Upper Tennessee.

6. Murray on the Arkansas.

7. Freshwater Lock and Calcasieu Salt Water Barrier on the GIWW West (Middle).

8. Franklin and Moore Haven Locks on the Okeechobee Waterway.

*Further investigation has determined that the NWS Inventory data for this lock are incorrect. Lock #1 on the Kentucky River is not a high-use facility.

9. Great Bridge Lock on the AIWW (entrance to Chesapeake Bay).

10. Lock No. 23 on the Erie Canal.

11. Black Rock Lock on the Niagara River.

12. Chittenden Salt Water Barrier on Puget Sound.

13. W.G. Stone Salt Water Barrier on Sacramento Bay.

(d) Data on Recreational Use of Ports and Harbors

The NWS Inventory reports data on approximately 220 commercial ports with recreational facilities, including marinas, boat slips and launching facilities. The largest number of ports with such facilities is found on the New Jersey/New York Coast and on Lake Michigan, followed by the Upper Atlantic, Lake Huron, and Chesapeake and Delaware Bays. In terms of marinas, the greatest number is found within the Port of New York, the Port of Sacramento, and the Port of Stockton. Large numbers are also recorded on the Hudson River; the New York State Barge Canal; Boston, Mass.; Jamaica Bay; Miami, Florida; the Connecticut River; and Seattle, Washington. Launching facilities (boat ramps) are generally insignificant in number in commercial ports.

RECREATION FORECASTING METHODOLOGY

Recreation demand was forecasted for four types of facilities (locks and dams, pools and channels, ports and harbors, and reservoirs). Separate forecasts were made for four different activity types in each setting: boating (including waterskiing), fishing, swimming, and shore-based activities (hiking, camping, picnicking, sightseeing, and "other"). In each case, future recreation demand was related to four classes of variables: present levels of recreational participation, socioeconomic characteristics of the potential user population, attributes of the specific recreational sites, and distance of the potential user population from the sites.

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NATIONAL WATERWAYS STUDY. ANALYSIS OF NAVIGATION RELATIONSHIPS --ETC(U)

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(a) Pools and Channels

Due to the large number of pools for which recreation use was forecasted, stepwise regression analysis was selected as the tool for making the forecasts. The advantages of using such an approach are two-fold: first, it provides the ability to base forecasts on the relationship between existing recreation use patterns and other existing factors which can be projected; and second, it provides the potential to make general forecasts for all cases, even though existing recreation use data are not available for all cases.

Regression equations were developed for each of four recreation categories: boating and waterskiing; fishing; swimming; and "other recreation" (i.e., land-based recreation, such as picnicking, camping, hiking, etc.). The independent variables tested in each equation included population, income, and amount of recreation area. Each of these variables is considered to be fairly standard for regression equations predicting future recreation use. Other standard factors, such as distance and competitive facilities, were incorporated into the population variable as described below.

Each equation, based on existing relationships between present recreation use patterns and the independent variables, was tested in order to determine its statistical validity for prediction. The SPSS computerized statistical package was used for this purpose. The equations were than used to forecast future recreation demand on the basis of the projected values of the independent variables. Values for 1985, 1990, 1995, and 2000 were forecasted.

1. Recreation Use Data. The recreation use data collected for calibration of the several predictive equations were in the form of annual recreation user-days. Such data were available from two sources prepared by the Corps of Engineers: the National Waterways Study (NWS) Inventory and Recreational Resource Management System (RRMS). These two sources differ fairly significantly in terms of level of geographic detail, format, and completeness of the data.

The NWS Inventory provides total 1976 recreation user-days which were reported by the various Corps districts. However, no distinctions were made between the number of user-days for each recreation type, thereby eliminating the opportunity to create separate regression equations for each type. In addition, the data were generally not available on the basis of individual pools. Instead, the user-days reflected those occurring along entire waterway segments or large subsegments.

The RRMS data, on the other hand, seemed to be somewhat more complete, with a finer level of detail. Information available in the Corps publication, 1977 Recreation Statistics, includes 1977 total annual recreation days for all projects having an annual visitation of over 5,000 recreation days, and percentages of total recreation days that are attributed to the various categories of recreation. Therefore, it was possible to determine the number of annual recreation user-days by recreation type for many of the navigation pools.

A potential source of error in the RRMS data, however, is that the data were reported by several hundred Corps project managers throughout the country. Although general guidelines were distributed to each project manager to keep responses as consistent in methodology as possible, some inconsistencies and failures to report accurate information are inevitable. In this respect, the two sources of data are probably somewhat comparable in that they are entirely dependent on the accuracy of the reporting units. Despite the potential for error, the RRMS data appeared to be the best source for the purpose of forecasting recreation use on navigation pools.

Nine categories of recreation activity that were provided in the RRMS data were combined to form the four categories being forecasted: boating/waterskiing, fishing, swimming, and other (i.e., picnicking, camping, hunting, sightseeing, and other). Each of the four categories created is considered to be unique in terms of its recreational requirements.

2. Recreation Attractiveness Data. The amount of area utilized for recreation is generally considered to be a measure of the attractiveness of a recreation site. It is assumed that the greater the area available, the

greater the recreation use. Therefore, the amount of recreation area was included as a potential independent variable for forecasting recreation use.

For the boating/waterskiing and fishing categories, the average total water acreage of each pool was used as a measure of recreation area, because water surface area is the limiting factor in both cases. On the other hand, the amount of shoreline available is most important for swimming, so pool shoreline miles were used as the area measure for that category. Ideally, only the number of shoreline miles dedicated to recreation should be used, but such detail was not available. Finally, the total recreational land acreage around each pool was used for the "other" recreation category, since it consists of primarily land-based activities. The RRMS Information System served as the source for the recreation area data used in equation calibration. Missing data were obtained and obvious inaccuracies were corrected through calculations from navigation charts.

For forecasting, it was assumed that all area information would remain constant over time.

3. Population Data. Population data were collected both from the Census and from the Bureau of Economic Analysis (OBERS Series E). However, the data required a significant amount of manipulation in order to be useful for equation calibration and forecasting. The basic types of data manipulation required were the calculation of 1977 county population values, the incorporation of the distance and competitive influence factors into the population values, and the calculation of county population values for the forecast years.

All counties located within approximately 50 miles of each waterway segment were identified. OBERS was then used to determine in which BEA economic area each county is included. For the counties, 1950 and 1970 population data were collected from the Census, while BEA area population data for the same years were obtained from OBERS. The change in each county's share of its associated BEA area's population during the twenty-year period was then determined in order to establish a trend of county growth in comparison to the larger BEA area growth.

Projected 1980 population information was also available for each BEA area. Interpolation of the data provided 1977 population values on a BEA area level. The percentage of 1977 BEA area population attributed to each county was determined by applying the 1950-1970 annual rate of ratio change. Finally, the 1977 county populations were calculated.

It was necessary to develop 1977 population values since the recreation user-days data reflected that year. Base year consistency was important to disaggregate the BEA area populations to a county level properly, because the former values were too broad.

Once the 1977 county populations were determined, it was necessary to allocate these populations among the various waterway navigation pools. The methodology incorporated both distance and competitive influence factors into the population values, instead of using such factors as separate variables in the equations.

For each pool along a waterway segment, the county population centers (usually county seats) within a fifty-mile radius were identified. Such counties were considered to be within that pool's sphere of influence. However, a county could be assigned to more than one pool's sphere of influence since many of the pools are close enough together to be within 50 miles of that county. The percentage of each county's 1977 population that potentially would travel to each pool was determined, based on the ratio of relative attractiveness is expressed as the decimal fraction of the linear distance from the county population center to the closest pool. This definition assumes that relative attractiveness is inversely proportional to linear distance. Ideally, distance should have been measured in terms of road mileage instead of linear mileage. Once again, however, the geographic scope of this project precluded the measurement of road mileage between each population center and navigation pool.

In order to determine the percentage of the county population which potentially could travel to a particular pool, the relative attractiveness of that pool was divided by the sum of total attractiveness of all pools within fifty miles of the county. The percentage was then applied to the total county population in 1977 to

derive the actual population that potentially would travel to the pool. For each navigation pool, all individual county populations that potentially would travel there for recreation were added together, providing the total population within that pool's sphere of influence that might actually seek recreation there.

Although this methodology incorporates distance as a means of distributing population to various pools, it is also necessary to consider distance a determinant of actual recreation use of the population within a given pool's sphere of influence. In other words, despite the fact that a given percentage of each county within a pool's sphere of influence would be likely to travel to that pool for recreation in comparison to other pools in the area, the number of people that would actually travel to the pool would vary depending on distance of the population centers.

For instance, if for a particular navigation pool the largest population centers were toward the periphery of its sphere of influence and the smallest population centers were close to the pool, the actual use of that pool for recreation purposes might be very low. In comparison, a pool having a lower total population within its sphere of influence would actually expect higher recreation use if its largest population centers are located closer to the pool.

This type of distance effect was also taken into account in the population variable. Several methods of incorporating the effect were developed and statistically tested during the equation calibration procedure. One method was to weight each county population that potentially would travel to each pool by the inverse of the distance, and then to sum the weighted populations for each county within a pool's sphere of influence. The second method was to develop three overlapping population rings based on distance from the navigation pool (i.e., less than or equal to 10 miles). It was assumed that one of the three rings would prove to be the most influential in determining recreational use. The method to be used and, in the case of the second method, the particular population ring to be used as the basis for the population variable, was decided following statistical testing.

The procedure used for calculating county populations for the forecast years is basically the same for 1977. The 1985, 1990, and 2000 BEA area populations were obtained from OBERS. Interpolation of 1990 and 2000 forecasts provided the 1995 BEA area populations. The four population sets were then disaggregated to a county level on the basis of the 1950-1970 annual rate of county-to-BEA area population ratio change. The future county populations were then distributed among the various waterway pools in the same fashion as for 1977. The effect of distance on actual recreation use of the population within a given pool's sphere of influence was taken into account using the methodology found to be most statistically significant for 1977.

4. Income Data. Income data were collected in much the same manner as population data, except that the county-to-BEA area ratio to be applied was based only on 1970 instead of the change in ratio from 1950-1970, as was done for population. The data collected were in terms of per capita income, utilizing the Census for 1970 county values and OBERS for BEA area values for 1970 county values 1970, 1980, and forecast years. For disaggregation to the various pools, per capita incomes were multiplied by population to yield total income of the people potentially traveling to a particular pool. Once this was done, total income was converted back into average per capita income.

5. Statistical Validity of the Predictive Equations. Four equation forms, each containing several variable combinations, were tested for each of the four recreation types: linear, semi-log, and log of the dependent variable. The basic structure of these equation forms is as follows:

linear: $\text{User days} = a_0 + a_1X_1 + a_2X_2 \ldots + a_nx_n$

semi-log: $\text{User days} = a_0 + a_1\ln x_1 + a_2\ln x_2 \ldots + a_n\ln x_n$

log-log: $\ln(\text{User days}) = a_0 + a_1\ln x + a_2\ln x_2 \ldots + a_n la x_n$

log of the dependent variable: $\ln(\text{User days}) = a_0 + a_1x_1 + a_2x_2 \ldots + a_nx_x$

From these potential equations, a single regression equation was selected for forecasting future user-days within each recreation type. The "best" equations were determined on the basis of statistical significance of each equation and their associated variables, the strength of relationship between the variables, and the other statistical criteria.

Simple bivariate correlation analysis was first performed between each pair of variables. This step indicates which independent variables are highly inter-correlated. The criteria for determining high inter-correlations were those at the .10 level of significance and those with at least a .50 strength of relationship.

Various combinations of potential equation variables, excluding inter-correlated variables, were then tested using stepwise regression analysis. The "best" equation for each use type was selected on the basis of a variety of factors (r^2, standard error, f-test of significance, t-test of significance and direction of the coefficients). The general equation forms that were identified initially as the "best" are as follows:

SWIM1 = .7016170 (SHOREMIL) - .0002751371(PRING3) + .06390658

r^2 = .31   standard error = 2.05

BOAT1 = .7316607 (WATER1) + .1759957 (PRING2A) + 2.962052

r^2 = .38   standard error = 1.25

FISH1 = .9260197(WATER1) - 2.933974(PCIRG3A) + .1488167 (PRING1A) + 12.35375

r^2 = .45   standard error = 1.50

OTHER1 = .8136663(LAND1) + .2726790(PRING1A) + 3.549388

r^2 = .61   Standard error: 1.50

SWIM1 = natural logarithm of the number of swimming recreation user-days

BOAT1 = natural logarithm of the number of boating and waterskiing user-days

FISH1 = natural logarithm of the number of fishing user-days

OTHER1 = natural logarithm of the number of land based recreation user-days

SHOREMIL = number of shoreline miles

PRING3 = total population within 50 miles

PCIRG3 = average per capita income of population within 50 miles

WATER1 = natural logarithm of the number of acres of water surface available

PRING2A = natural logarithm of the total population within 20 miles

PCIRG3A = natural logarithm of the average per capita income of population within 50 miles

PRING1A = natural logarithm of the total population within 10 miles

LAND1 = natural logarithm of the number of acres of recreational land available

Although the statistics for these equations were the "best" in comparison to all of the other equations tested, the r^2 values are considered to be only moderate. They are, however, in general accordance with the r^2 values obtained in other recreation studies. With one exception, all coefficients were significant at the .05 level. The exception: the PCIRG3 variable in the swimming equation was significant at the .10 level.

After further analysis of the suitability of the cross section equations for forecasting recreation use, it was found that the two equations containing some form of per capita income variable (swimming and fishing) tended to produce obviously inaccurate forecasts. In both cases, the per capita income coefficients were significantly larger than the population coefficients, thereby exerting a stronger influence on the forecasts than population. Ordinarily, this would not cause difficulties, but in the OBERS data the percentage change in per capita income during each future period was usually significantly greater than the percentage change in the population.

Due to the problems in forecasting swimming and fishing user-days, new "best" equations were developed for those recreation types. For both equations, all per capita income variables were eliminated from analysis, such that the equations were based wholly on population and recreation attractiveness. Since the boating and "other recreation" equations already excluded income, these were not altered. The revised equations for swimming and fishing are as follows:

$$\text{SWIMI} = 1.206658\ (\text{SHORE}) - 0.4926553\ (\text{PRING3A}) + 8.542506$$

where $r^2 = .34$ standard error = 2.05

$$\text{FISHING} = 2179.507\ (\text{WATER}) + 1088.342\ (\text{PRING3A}) - 13418.58$$

where $r^2 = .29$ standard error = 4551.43

The particular characteristics of each site are taken into account by using the present level of recreation use as the starting point for each forecast where data are available. The equations derived above are used to determine the growth factor rf/rb to apply the base year recreation use figures. Mathematically this can be represented as follows for each site:

$$R_F = R_B \frac{r_F}{r_B}$$

where: R_F is the forecast recreation use

R_B is recreation use in the base year

r_F is the recreation use forecast by using the regression equation

r_B is the base year recreation use predicted by the regression equation.

This forecast method assumes that the relative attractiveness of each site will not change in the future. Clearly, this assumption does not hold where any particular site would experience future improved access or site development more than others. However, when site recreation use is summed to the segment level, the forecast problem posed by this assumption is virtually eliminated.

(b) Locks and Dams

Forecasts were made for each of the locks and dams corresponding to the navigation pools for which forecasts were made in previous analysis. However, since some of the so-called pools on the list are not true navigation pools (i.e., they are free-flowing waterways without associated locks and dams), they were not considered in the lock-and-dam analysis. The following pools were not considered in the lock-and-dam analysis:

1. Chicago Ship Canal.
2. Calumet Sag Channel.
3. Below La Grange (Illinois Waterway).
4. Missouri River.
5. Muskingum River.
6. Big Sandy River.
7. Below Barkley (Cumberland River).
8. Below Kentucky L/D (Lower Tennessee River).
9. Black/White River.

10. Below Norrell L/D (Arkansas-Verdigris Rivers).

11. Below Jonesville (Ouachita-Black & Red).

12. Below Coffeeville (Black Warrior and Tombigbee).

13. Below Claiborne L/D (Alabama-Coosa Rivers).

14. Below Woodruff (Apalachicola River).

15. Columbia River.

Regression analysis was also used as the method for making the recreational use forecasts for locks and dams. However, only one equation was developed for predicting the number of recreational craft passing through each lock. It was assumed that the best predictor of recreational craft passing through locks would be the number of user-days of boating on the associated pools. This variable can be considered a proxy for both boating attractiveness and boating access. Once that variable was forecasted for the future years, it could be used for predicting the number of recreational craft passing through each lock.

Once again, the SPSS computerized statistical package was used for developing the predictive equation from 1977 data. Forecasts of recreational craft passing through locks were then made for 1985, 1990, 1995, and 2000.

1. Recreational Craft Lockage Data. Base year data for the dependent variable were collected from Performance Monitoring System (PMS). Data are similar to the RRMS data used in the pools analysis in that the data were collected from the individual project sites. Therefore, the data are also subject to the same potential errors, such as inconsistencies in counting methods and failures to report accurate information. By the same token, the data are substantially complete, with only about five percent of the locks under analysis lacking the necessary information.

The PMS source provides recreational craft data broken down by month and direction. However, only annual totals for both directions combined were collected for use in the analysis. The form of the independent variable (i.e., boating user-days) reflects annual totals and would be difficult to accurately disagggregate by month or season .

A second data source of recreational craft information is the Corps of Engineers' NWS Inventory. However, as with other types of data in the inventory, the recreational craft lockage data are rather sketchy and incomplete. Therefore, this source was not used for any of the locks and dams.

2. Boating and User-Days Data. Data for boating user-days on associated navigation pools were developed from the pools analysis. Values for 1977 were used to calibrate the regression equation. Forecast year values were then used to generate future recreational craft estimates. The data are complete for all lock and dam/pool segments.

One potential source of error is that the boating user-days also include waterskiing. Since it is unlikely that waterskiers will pass through locks, the inclusion of waterskiing user-days in the independent variable may somewhat distort the true relationship between boating use and recreational craft lockages.

3. Statistical Validity of the Predictive Equation. Bivariate correlation analysis was initially performed to determine the strength and direction of the relationship between recreational craft passing through locks and the number of boating user-days. Four different correlation combinations were tested to determine the best relationship.

The highest and most significant relationship exists between the number of recreational craft and the natural logarithm of the number of boating user-days in adjacent pools, although the correlation is actually only moderate in strength. It is easily significant at the .05 or even the .01 level. The regression equation formed by

ʟnis combination was also found to provide the greatest statistical validity. The derived equation is as follows:

$$\text{RECCRAFT} = 5.448802\ (\text{BOATL}) - 11.36243$$

$$\text{where } r^2 = .29 \quad \text{standard error} = 28.02$$

The F- and t-statistics indicate that the equation is significant at the .01 level.

(c) Reservoirs

Recreation demand was forecast on the four projects with authorized navigation releases, (i.e., Oolagah, Tygart, Buford, and Gavins Point) due to the potential impact of navigation releases from these reservoirs on water levels and recreational use potential. These four reservoirs represent a spectrum of geographical areas, diversity in associated recreational activity, and a variety of socioeconomic characteristics in their immediate areas. Thus, future recreation demand was forecast separately for each reservoir rather than trying to find a general equation applicable to all facilities of this type.

Total activity days in 1977 for four basic types of activities (i.e., swimming, boating and waterskiing, fishing, and "other") for each individual reservoir. This activity was then related to the 1977 population and per capita income of counties within 50 miles of each reservoir. These characteristics were then forecast for the related counties using OBERS forecasts disaggregated to the county level on a share of growth basis, as in the preceding pools analysis. Finally, the recreation activity days on each reservoir were forecast as a function of increasing population and income by activity type.

The data collected for use in recreation use forecasting on reservoirs were similar to data collected during the pools analysis. The following data were collected:

1. Names of all counties and their largest city or town within fifty miles of the nearest point of each

reservoir. This information was obtained by direct measurement from an appropriate large scale map.

2. The distance of the largest city or town in each county to the reservoir, obtained by direct measurement, in linear or air miles from the city to the closest point on the reservoir.

3. Population and per capita income figures for each county for the years 1950 and 1970. Data were taken from Census Bureau figures.

4. Projections of population and per capita income for regions in which pertinent counties are included for the years 1980, 1985, 1990, and 2000. Projections were obtained from the 1972 OBERS projections, Series E, prepared by the Department of Commerce, Bureau of Economic Analysis.

5. The total visitation or total number of user-days attributed to each reservoir. These data were taken from the RRMS data compiled by the Corps of Engineers.

6. The percentage of participation by specific activity type for each reservoir, also available in the RRMS data system.

Once population and per capita income estimates and projections by county for 1977 and the five-year intervals from 1980 to 2000 were calculated, it was assumed that recreation demand is a function of population, income, and the distance of the county from the recreation resource. The statistics developed during the pools analysis indicate that there is a relationship between recreation use and these factors. It was further assumed that the distance of the county from the resource is the distance from the largest town or city in that county to the recreation resource.

Using 1977 as a base year, the relationship between the population income and distance variables and recreation activity demand is assumed to be:

$$R_{a_{xv}} = K_{av} \sum_{x=1}^{n} \frac{P_{c_x} I_{E_X}}{D_C}$$

Where: $R_{a_{xv}}$ = Recreation user-days in activity A in year X at reservoir V

P_{c_x} = Population in county C at year X

I_{c_x} = Per capita income in county C at year X

D_c = Distance from county population center to reservoir

K_{av} = A constant for activity A at reservoir V $= \dfrac{R_{av}}{\dfrac{\sum_{c=1}^{n} P_{c_{77}} I_{c_{77}}}{D_c}}$

Where: R_{av} = the total number of user-days of activity A reservoir V in 1977

From this equation, recreation activity days were projected for four reservoirs for four activity types and for five different years to 2000.

(d) Ports and Harbors

Recreation use forecasting for ports and harbors was performed for 10 waterway segments. These segments are all situated either on the Atlantic Coast, Pacific Coast, the Gulf of Mexico or the Great Lakes. Any port and harbor identified by the National Waterways Study (NWS) Inventory as having at least 100 recreational boating slips and/or 1,000,000 commercial tons of traffic were considered to be eligible. Ports and harbors to be studied in greater detail were selected from this list on the basis of which one would potentially be able to provide the information needed to forecast recreational use.

The following ports and harbors, by waterways segment, were selected:

Segment 33 - Florida Gulf Coast	Port of Tampa.
Segment 41 - Chesapeake and Delaware Bays	Port of Washington, D.C.
Segment 42 - New York/ New Jersey Coast	Port of New York.
Segment 44 - Upper Atlantic	Boston Harbor.
Segment 46 - Lake Erie	Erie Harbor.
Segment 47 - Lake Huron	St. Clair Harbor.
Segment 50 - Puget Sound	Port of Seattle.
Segment 53 - Oregon/ Washington Coast	Portland Harbor.
Segment 55 - San Francisco Bay	Oakland Harbor, Port of Sacramento.
Segment 46 - Central/South California	San Diego Harbor.

1. Forecasting Methodology. Recreation use forecasts for the ports and harbors analysis were limited to boating, since this activity is the predominant form of recreation in most port and harbor areas. In order to forecast the recreational boating use, two types of data were collected: the existing number of recreational boat- ing facilities available in each port and harbor and the growth rate of boat registration in each relevant state. These data were used in conjunction with several assump- tions in order to derive future estimates of boating activity on peak days.

The following equation was used to develop the forecasts:

$$B_n = B_o(1 + g)^n$$

Where: B_n = active harbor fleet during a peak day in the future year

B_o = active harbor fleet during a peak day in the base year

g = growth rate of boat registration in the associated state(s)

n = exponent for the number of years into the future for which the forecast is performed

It was not always possible to perform forecasts for every port and harbor studied, since base year data were unavailable in some cases. The number of boats presently in use in the ports and harbors on a peak day was estimated on the basis of the number of recreational slips and launching ramps available. This information was available for some of the ports and harbors from the NWS Inventory, although only the number of slips (or no information at all) was available for others.

It was hoped that information could be obtained for those areas for which inventory data were lacking through a telephone survey. It was also hoped to update, improve, or verify the data taken from the Inventory through the survey. People contacted included members of the various ports authorities, the Coast Guard, state recreation departments and/or marina operators. Besides trying to obtain data on the number of slips and launching ramps, an attempt was made to collect data concerning number of marinas, percent of slip utilization, definition of port/harbor boundaries, existing recreation-navigation conflicts, etc. Unfortunately, much of the information requested could not be obtained.

The number of recreational craft in use within a port or harbor during a peak day was estimated in the following manner.

(a) Assume one boat per ship, unless the utilization rate obtained through the telephone survey indicates less than 100% utilization.

(b) Assume that 75% of the boats moored in the harbor actually leave their ships during a given peak day.

(c) Assume that 40 boats utilize each launching ramp during a given peak day.[1]

(d) Existing total recreational boats in use within the harbor during a peak day is estimated by adding the number of moored boats that leave their ships and the number of transient boats entering the harbor from launching ramps.

This approach represents the maximum usage of an area on a given day. Actual levels of recreational boating may be somewhat less.

2. Growth Rates for Registered Boats. Data pertaining to the totals for each state do not represent all recreation boat types that could be expected to frequent port and harbor areas. In fact, the types of craft that are included in the totals differ according to the particular state. As a result of these differences and the failure to include all boating types expected to travel in ports and harbors, the registration growth rates do not provide a complete picture.

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1 This 40 Boats per launching ramp estimate is based on standards of use prepared by the Department of Interior's Bureau of Outdoor Recreation in Outdoor Recreation Space Standards. It is reported that the Corps of Engineers, the Federal Power Commission, the Bureau of Reclamation, and the Louisiana Parks and Recreation Commission all have used this standard.

However, it is anticipated that these rates are sufficiently accurate for use in forecasting total recreational boating use in ports and harbors.

The growth rates were established by performing regression analysis on six data points for each state. The correlations between boat registration and year for every year were very high, with the lowest correlation (.61) occuring in Michigan. Although figures for Washington, D.C. were available, these were not used, since the correlation was very low. Rather, total registration in Maryland, Virginia, and Washington, D.C, was used to establish the growth rates for the Port of Washington, D.C.